Appendix H

Lessons Learned for the Tensiometer Probe Design

Appendix H

Lessons Learned for the Tensiometer Probe Design

Author: Blair Grover

H-1. INTRODUCTION

Throughout the year 2001, several specially designed instrumented probes (i.e., also referred to as the Type B probes) were installed into the Subsurface Disposal Area (SDA) at RWMC. Some of the probe types were designed at the INEEL, and others were purchased commercially. As of the date of this paper, many of the Type B probes are not performing as anticipated or expected. There are many potential reasons for the probes' present inability to perform.

H-1.1. Scope

The purpose of this paper is to document the identified problems with the INEEL developed tensiometer probe. Sixty-six instruments were manufactured and installed into the SDA at RWMC. Installation of the probes was in August and September of 2001. Since their installation into the SDA, performance of the probes have been substandard to expected results. Various different conditions have affected the performance of the probe, and this paper identifies known problems with the probe that have been observed and noted by field activities.

This paper assumes that the current requirements of the technical and functional requirements (T&FRs) remain unchanged. If the project requirements that guided the INEEL design change, other measures can be taken to address some of the issues that have presented themselves over the past year since installation of the instrument into the SDA. This paper focuses on the current design and fixes meeting the project documented T&FR requirements.

H-2. IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY TENSIOMETER PROBE

INEEL tensiometers have been placed into the SDA waste at RWMC. Of the 66 probes, eight have been deemed to be nonfunctional caused by electric sensor feedback, and the status of the remaining 58 is undetermined. It is assumed that the remaining nine tensiometer probes are operational or can be placed into operation with modifications to ground surface caps. Some tensiometers have been functional since installation, yet others hnction intermediately. It may be possible that intermediate hnction is caused by this last year's dry conditions. Following is a list of identified Tensiometer problems accompanied by a list of potential solutions.

H-2.1 Problem 1: Probe Cap to Probe Casing Interface

Flexible-tubing connections at the ground surface cap have presented problems. The length of the flexible tubing needed to make the connection onto the probe cap in addition to the length of the SST tubing connections on the cap promote pinching. Additionally, when the cap is threaded into the probe casing, the problem compounds from the twisting needed for engagement. Most instruments were filled with water by removing the probe cap and thus removing the pinched portion of the flexible tubing.

H-2.1.1 Water Addition from Ground Surface to Instrument

During field maintenance activities, there were several problems with filling the instruments with water. Water addition was first attempted during winter months after installation. Identified problems with water addition include:

- Pinched flexible tubing caused by length of connection points on probe cap, especially a problem with shallow probes. Too much tubing is needed to interface with the cap and then must be pushed into the probe casing after attachment to the cap.

- Twisting of probe cap to thread into probe casing promotes pinching of flexible tubes inside probe casing, especially a problem with shallow probes.

- Freezing of water when water addition is attempted to instrument during winter months from pinched flexible tubing. If the flexible tubing is pinched when water is added to the instrument in freezing conditions, a blockage occurs from freezing water.

H-2.1.1.1 Potential Design Solutions. Potential design solutions include:

- Shorten SST tube connections from probe cap. Shorting SST tubes will reduce the amount of flexible tubing that must be placed down into probe casing.

- Shorten thread on cap for interface to probe casing. Reduce number of threads to 1/2 or 3/4 thread for threading cap to probe casing. Reducing number of threads and length of cap interface to probe casing will reduce the amount of flexible tube twisting and reduce the amount of flexible tube to be placed down into probe casing.

- Provide an additional section of casing or spacer for cap installation. This will give more room for flexible tubing in probe casing and thus prevent pinching of the tubing. Complications will most likely arise from this method because of more complicated field connection techniques and from the nonmetal double barrier requirements of the T&FRs.

H-2.1.2 Tensiometer Probe Valve Operation

During field maintenance activities, there were some troubles with the valve operations of the instrument. Several issues arose here with valve operation. **A** hand-held readout logger was connected to the probe, and water was added to the lower sensing portion of the instrument. Pressure to operate the valve was increased until the sensor indicated that water was introduced to the sensing portion and verified by the hand-held readout. **A** few instruments did not respond to this operation. Possible causes of operation failure include:

- Sealant used to seal instrument valve sealed air holes in valve configuration. The 24-hour wait before testing during fabrication was eliminated because of time constraints. I feel this is one of the most likely candidates for valve nonoperation. Function was not verified just before installation.

- Incorrect flexible tubing connections. This would operate incorrect valve sequence.

- Damage of valve during sonic installation. Unlikely, as there were no indications during prototype testing.

- Damage of valve because of bending of instrument from installation. Verification of this failure is not possible since retrieval is not an option.

- Blockage still introduced in flexible tubing. Even with removal of cap, the flexible tubing may still be pinched at some point in the probe casing. I feel this is unlikely because of the pressure that can be applied is up to 100 psig.

H-2.1.2.1 Potential Design Solutions. Potential design solutions include:

- Future production of instruments needs to invoke the 24-hour drying period of the sealant used in the valve assemblies. Increase hole size in valve cups to prevent sealant closing off airports. Verify valve operationjust before installation.

- Verify correct tubing for connection to cap from above operations.

- Verify valve operations in cold test pit with instruments to see if sonic installation is damaging valve(s)

- Verify structural capacity of probe by installation into area of Cold Test Pit that has hard objects like rocks or concrete below ground surface.

- Insert visual probe camera into instruments that have valve hnction verified as not working and examine flexible tubing connections. May provide insight to other causes.

H-2.1.3 Other Identified Troubles with Probe Cap

Other potential performance enhancement features were identified during installation and field maintenance activities. These features include:

- Threading on and off of probe cap cover laborious. There are numerous threads on the cap cover

- Wire gage of instrument sensors difficult to connect to Turck connector

- Tubing colors incorrectly identified for connection to cap from instrument.

- Bundled flexible tubing hard to split and work with in field.

- Cap materials requirements may be reduced. Potential cost savings.

- Location of Turck connector from probe cap to data logging system difficult to work around when removal of probe cap from casing is necessary.

H-2.1.3.1 Potential Design Solutions. Potential design solutions include:

- Reduce number of threads on cap cover. Thread only portion of cap that interfaces with probe casing and cap cover. Reduce threads to *3* or 4.

- Choose more suitable colors (fluorescent colors were poor choice) for tubing and verify tubing color to instrument hnction before installation.

- Use individual flexible tubes from instrument.

- Increase wire gage of sensor wiring that runs up the probe casing after the instrument.

- Reduce complexity of cap and reexamine materials used for construction. May provide cost savings for future instrument productions.

- Relocate Turck connector or countersink deeper into cap.

H-2.2 Problem 2: Instrument Sensor Feedback

There have been several different instrument issues with sensors. It is not the intent to cover issues associated with connection from the instrument to the data logging system, and those issues are not discussed. Direct failure of the instrument sensors selected has been less than 12%. Failure percentage is based on Hopi Salomon and Joel Hubbell's indication that eight installed instruments are not recoverable. Failures have been from water addition to sensing portion of instrument not possible to not getting a signal from one of the two sensor installed in the instrument.

H-2.2.1 Failure of Instruments Sensors

Failures of instrument sensors identified include:

- Either soil gas or matric potential sensor providing no signal at all.

- Either soil gas or matric potential sensor providing fluctuating signals

- Valve for water filling of sensing portion of instrument not operating. Instrument hnction not possible with this mode of failure.

- Some instruments hnction for a period of time and then stop responding.

H-2.2.1.1 Potential Design Solutions. Potenital design solutions include:

- Use the visual probe camera on select instruments and look at sensor lead to instrument. Identify if sensor lead was torn loose from the instrument.

- No solution to identified item. Sensor internal electronic most likely damaged from sonic or installation.

- Use visual probe camera on selected instruments identified with this problem and inspect tubing for kink or pinch points.

- Variable solutions and causes for this mode of failure, which include:

  - Season was too dry for instrument hnction.

  - Perform calibration check on sensors to verify porous SST seals and material not cracked. Verification can be from the 8-psig vacuum applied to porous SST section of instrument.

  - Investigate response of porous SST with voids around material. Lab conditions for previous tests were ideal, and soil was packed around instrument. Hydraulic connection to surrounding soil or waste may give results being recorded. What effects does this have on instrument?

- Investigate area requirements of porous SST for sensing area needed. No investigation in this area has been performed to my knowledge.

H-2.2.2 Other Possible Issues

Freezing of water in the sensing portion of the instrument may have split the porous SST material. Verification of integrity of the porous SST may be accomplished by a calibration of the instrument-sensing portion.

H-2.3 Problem 3: Instrument Installations

During field installation activities there were items identified that would hinder installation of all probes that had either electrical leads, flexible tubing connections, and both electrical leads and flexible tubing connections.

H-2.3.1 Issues with Probe Installation

The following items cover issues with installation of the probes into the SDA:

- Push shoe issues from the drill rig to the probe casing had galling and stripping thread issues.
- Need more space for tubing and wiring through push shoe. Need tubing and electric lead holder mounted higher on drill string to hold tubing and wiring to prevent pinching or cutting of tubing and electrical leads. Previously, they used duct tape and tapped the tubing and wiring to the drill string. The hook we had designed did not hold the tubing high enough on the drill string and presented problems.
- TPR for installation of probes. Limit the number of rotations that the operator can use to engage the drill string to the probe.
- Perform several dry runs of installation and assembly of the probes with the field crew.
- Verify sensor wiring and sensor operation right before and after installation. Use hand-held instrument, such as that used for calibration.
- Bundled tubing hard to work with. Prevents replacement if needed.
- Correctly identify tubing colors for operation and connection to cap.

H-2.3.1.1 Potential Design Solutions. Potenital design solutions include:

- Heat treatment of the interface push shoe to the probe casing threads would solve potential problems here. Material use in push shoe was not heat treaded in previous installation efforts
- Redesign push shoe for easier installation into probe casing. Open up tubing and electric lead hole to prevent pinching and cutting. Design shoe so that the threaded connection to the probe casing is made by hand and then the drill string just pushes on to engage.
- Revise TPR for installation of probes to limit the number of turns that can be used to engage the probe casing. If engagement is not accomplished in 4 to 5 turns, the operator needs to stop, reverse

rotate the number of turns made, and attempt to reengage the probe casing. The above solution to redesigning the push shoe also addresses this issue.

- Perform cold tests with field crew and design engineer to become more familiar with delicate portions of instruments. Get them more up to speed on how the instrument works and the assembly. Possibly install an instrument in the Cold Test Pit for training purposes only.

- Field verify sensor operation (valve operation and correct tubing connections) before instrument installation.

- Use individual tubes from instrument.

- Field verify tubing connection operations before installation.

H-2.3.2 Other Identified Issues

The current field equipment used on the tensiometer is cumbersome to work with.

H-2.3.2.1 Potential Design Solutions. Fabricate a boxed system for filling and calibrating. The current systems are very cumbersome to work with. **A** cleaner ground-level boxed system would aid in diagnosis of problems and field maintenance activities.

H-2.4 Problem 4: Instrument Fabrication Issues

During the mass fabrication efforts at Northwest Machine and in-house fabrication efforts, several issues surfaced. These issues are associated with the lysimeter and tensiometer instruments.

H-2.4.1 Issues Noted During Production Runs

The following items were noted during the production runs:

- Callout slip fit where tubing and other items mate together. Clearances were a problem during mass production.

- Identifier items identified during mass production.

- Wording for paperwork required for production of probes. There was a ton of paperwork, especially the travelers during mass production.

- Can an alternate material be used for the tensiometer valve bodies (currently, Nitronic 60 material). Potential cost savings?

- Check all tolerances on valve bodies to see if they can be relaxed. High area of complexity on machining.

- No contamination issues to date. Can we relax the requirements for double barriers?

- Specify roundness on the porous SST material. The ends of some of the material were so out of round that the material was unusable.

- Some porous SST when installed onto instrument split when the tip was threaded onto the instrument to form the sealed sensing portion of the instrument.

H-2.4.1.1 Potential Design and Fabrication Solutions. Design and fabrication solutions include:

- Change wording on drawings were slip fit of items is mated together for welding.
- Incorporate IDs into drawings for as-built. This effort is already underway.
- Be more careful on wording for paperwork required for production of probes. Do not require duplicates of paperwork.
- Finite element analysis to identify material needs for tensiometer bodies.
- Revisit drawing requirements on tolerances.
- Revisit T&FR document.
- Specify roundness on the porous SST material so that all material received is usable.
- See solution above.

Appendix I

Data and Charts from Lower Sensor Field Validation: DU-10-TI, 2 and 3

Appendix I

Data and Charts from Lower Sensor Field Validation: DU-10-T1, 2 and 3

Author: Blair Grover

Upper Sensor	Lower Sensor	Source	Pressure	1054.6	Upper Sensor	Lower Sensor	Source
759.73	771.97	742.7	Barometric	871.4	72.04	73.2	-128.7
670.20	683.70	668.5			63.55	64.83	-202.9
574.44	586.99	570.8			54.47	55.66	-300.6
466.87	479.10	471.2			44.27	45.43	-400.2
367.11	381.24	371.5			34.81	36.15	-499.9

OFFSET

15.66

Corrected Lower Sensor with OFFSET

756.31

668.04

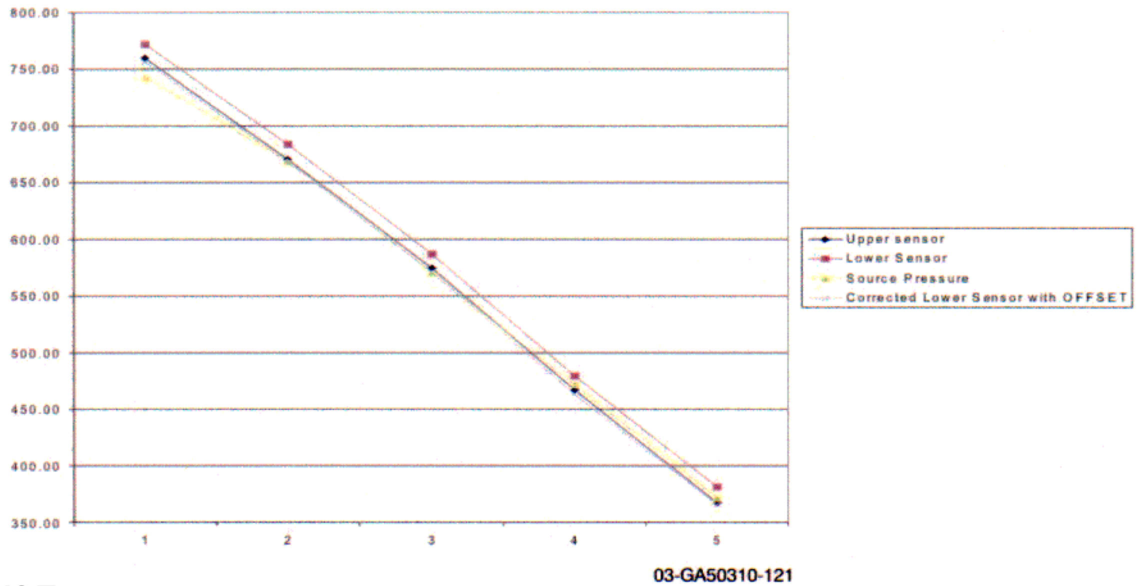
571.33

463.45

365.58

Delta to Source	Delta to Source	Delta Head on Lower
17.03	29.27	12.23
1.70	15.20	13.50
3.64	16.19	12.55
-4.33	7.90	12.23
-4.39	9.74	14.13

This unit does not have much water left in it. It needs to be refilled from ground surface.



DU-10-T1

Upper Sensor	Lower Sensor	Source Pressure	1054.6	Upper Sensor	Lower Sensor	Source
774.50	*830.92*	788.95 Barometric	872.04	73.44	78.79	-83.09
673.99	727.46	678.74		63.91	*68.98*	-193.3
572.96	624.85	578.64		54.33	59.25	-293.4
467.50	516.12	472.34		44.33	48.94	*-399.7*
366.26	413.61	371.94		34.73	39.22	-500.I

OFFSET

44.47

Corrected Lower Sensor with OFFSET

786.45

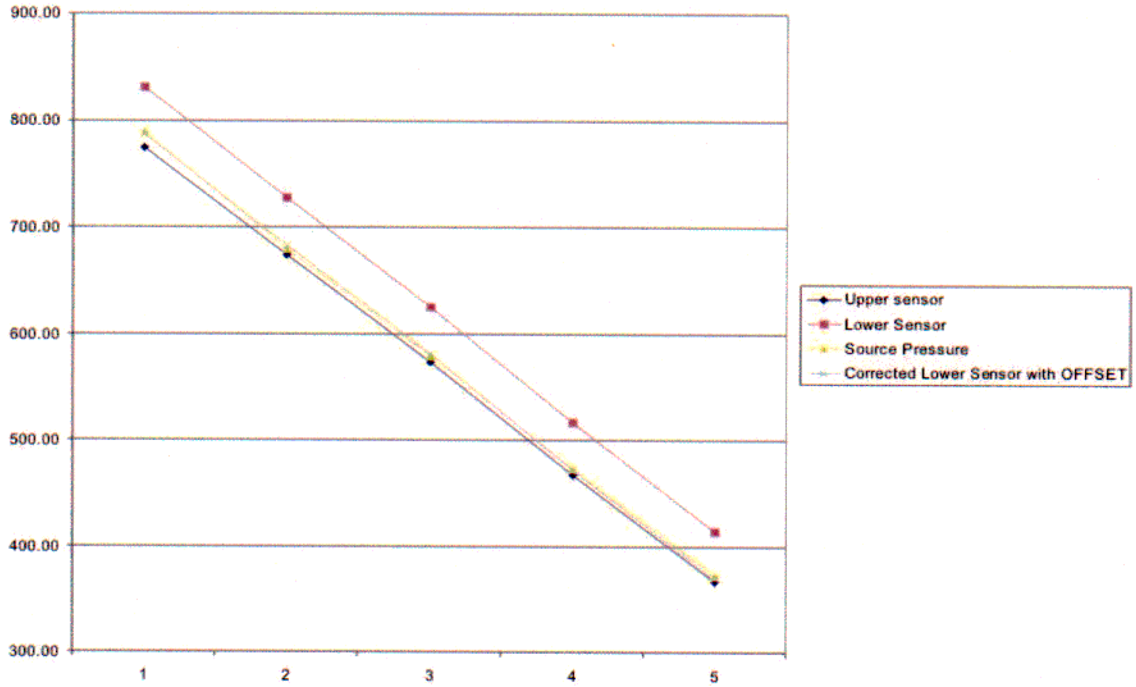
682.99

580.38

471.65

369.14

Delta to Source	Delta to Source	Delta Head on Lower
-14.45	41.97	56.42
4.75	48.72	53.47
-5.68	46.21	51.89
-4.84	43.78	48.62
-5.68	41.67	47.35



03-GA50310-122

DU-10-T2

Upper Sensor	Lower Sensor	Source Pressure		1054.6
878.90	931.32	858.76	Barometric	872.26
768.80	821.64	774.76		
661.02	715.97	667.26		
562.63	605.76	568.76		
467.29	493.34	473.86		

Upper Sensor	Lower Sensor	Source
83.34	88.31	-13.5
72.9	77.91	-97.5
62.68	67.89	-205
53.35	57.44	-303.5
44.31	46.78	-398.4

OFFSET

44.93

Corrected Lower Sensor with OFFSET

886.39

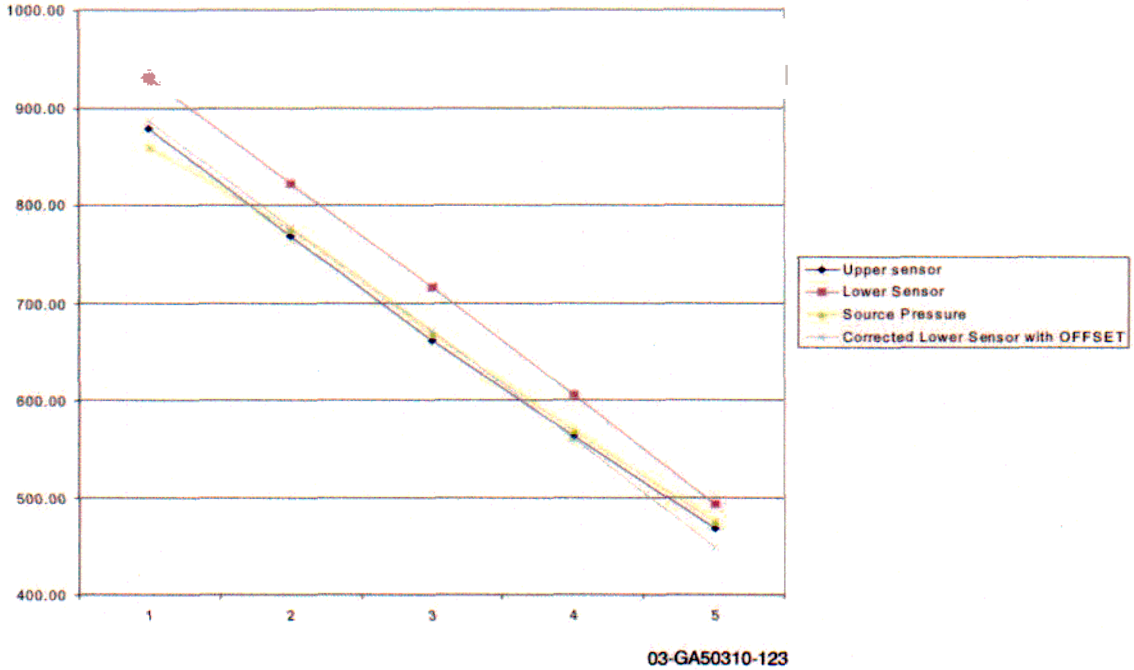
776.71

671.04

560.84

448.42

Delta to Source	Delta to Source	Delta Head on Lower
20.14	72.56	52.41
-5.96	46.88	52.84
6.24	48.71	54.94
-6.13	37.00	43.13
-6.57	19.48	26.05


1000.00
900.00
800.00
700.00
600.00
500.00
400.00
1
2
3
4
5
Upper sensor
Lower Sensor
Source Pressure
Corrected Lower Sensor with OFFSET
03-GA50310-123

Du-10-T3

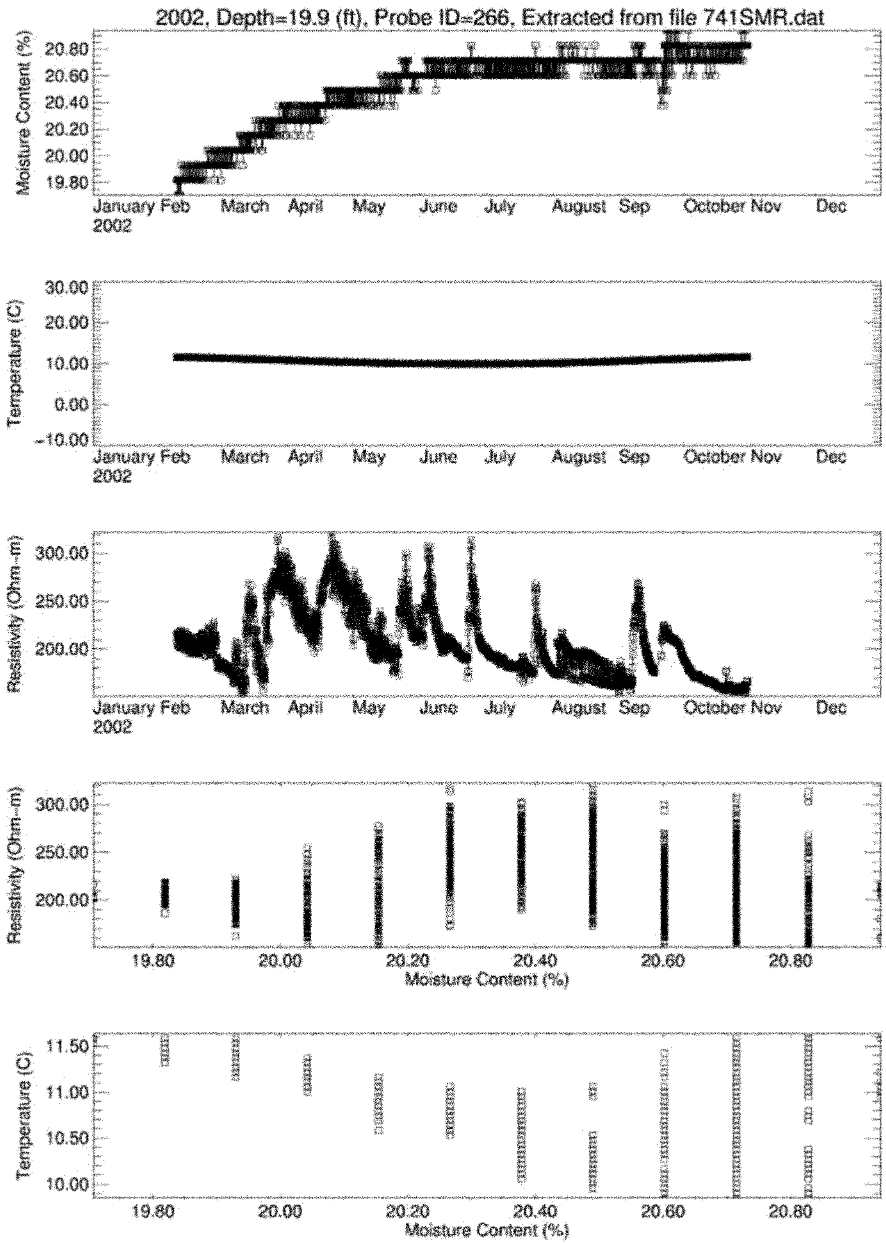
Appendix J

Soil Moisture Probe Data

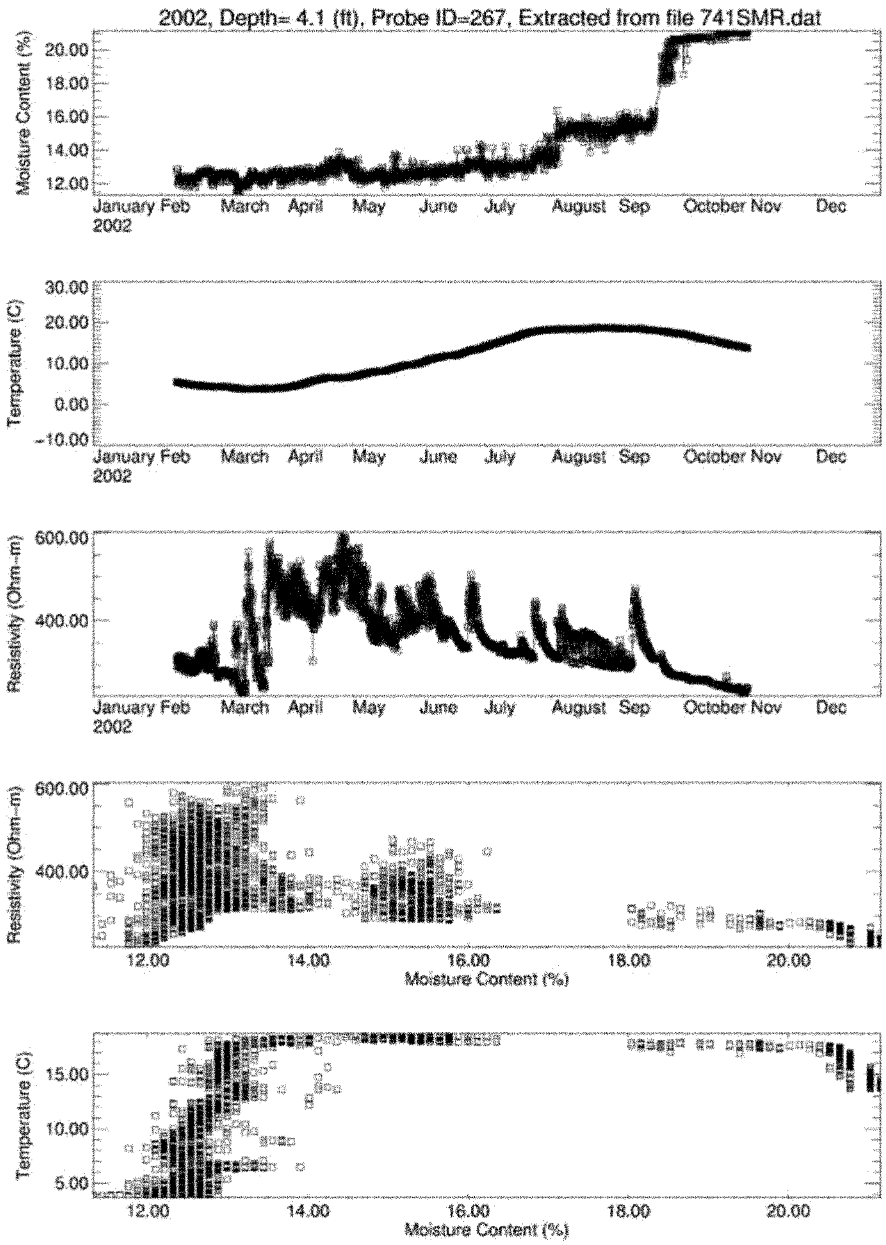
Appendix J

Soil Moisture Probe Data

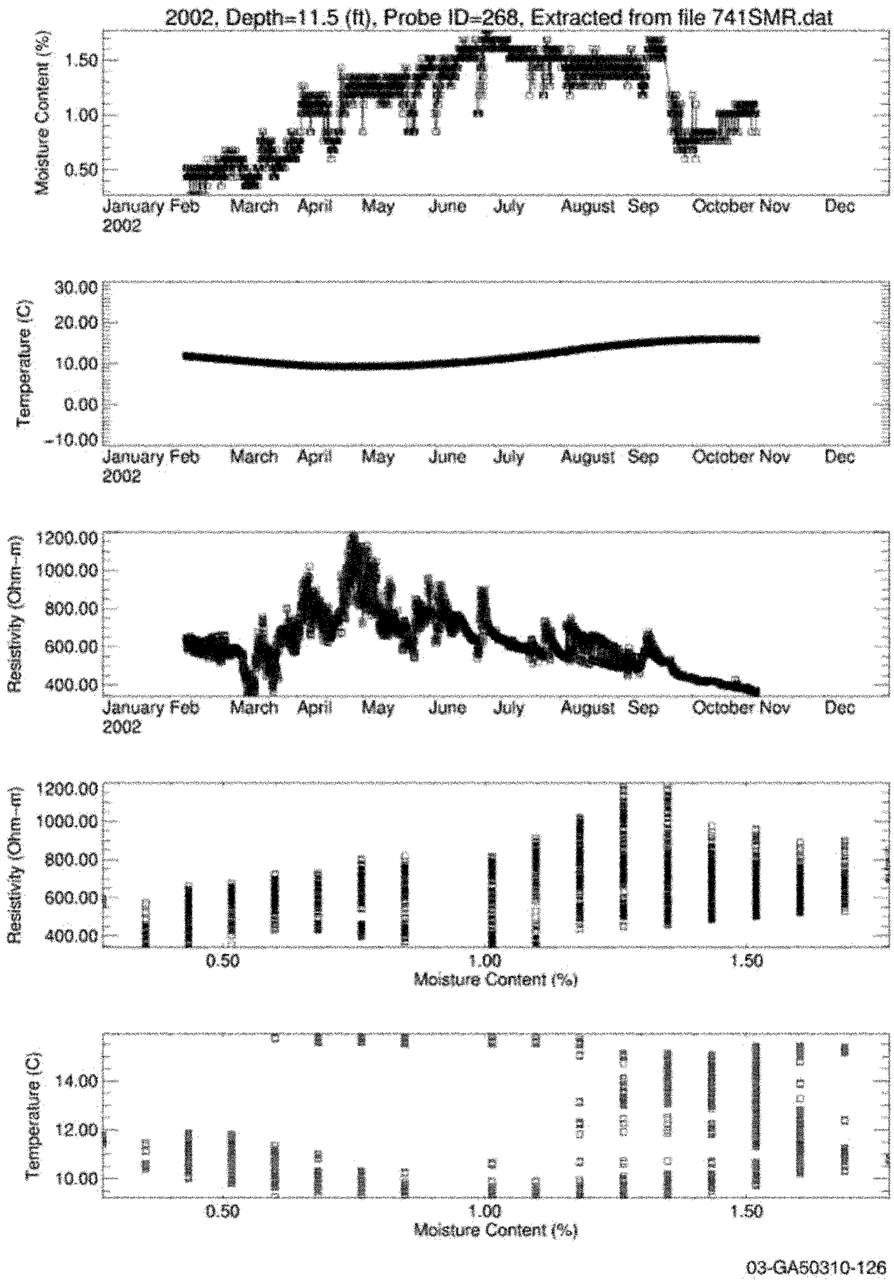
This appendix includes soil moisture probe data for the Subsurface Disposal Area in FY 2002. The data have been screened and evaluated and are based on the raw data from the soil moisture probes. The raw data were collected on a PC hard drive at the RWMC. The screened data files will be loaded onto a project-specific database maintained on Hbb2. The probe ID provided with the tables can be referenced to the probe ID in the Probe Attribute Table (see Table B-1 in Appendix B) and thereby cross-referenced to well ID and probe name and location.

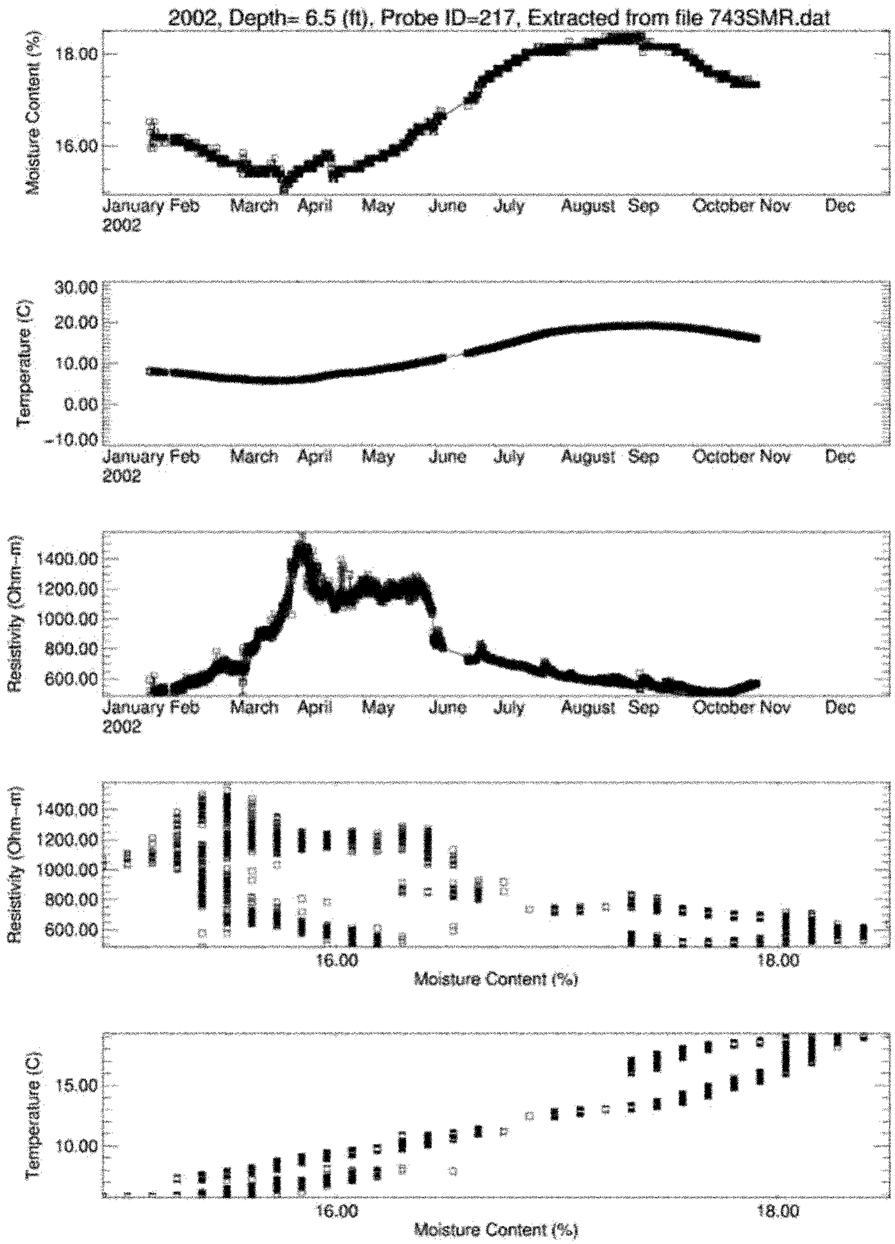


03-GA50310-124

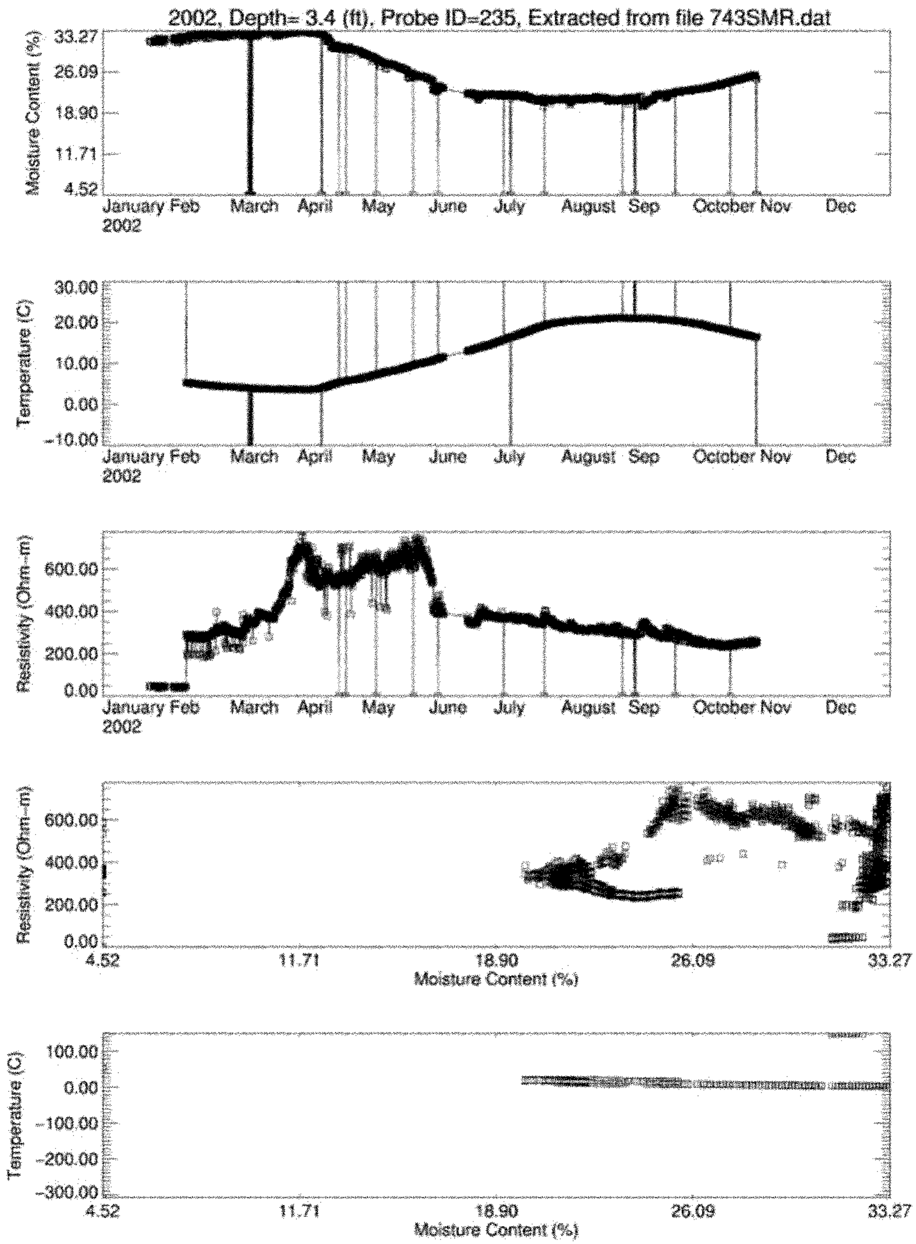


03-GA50310-125

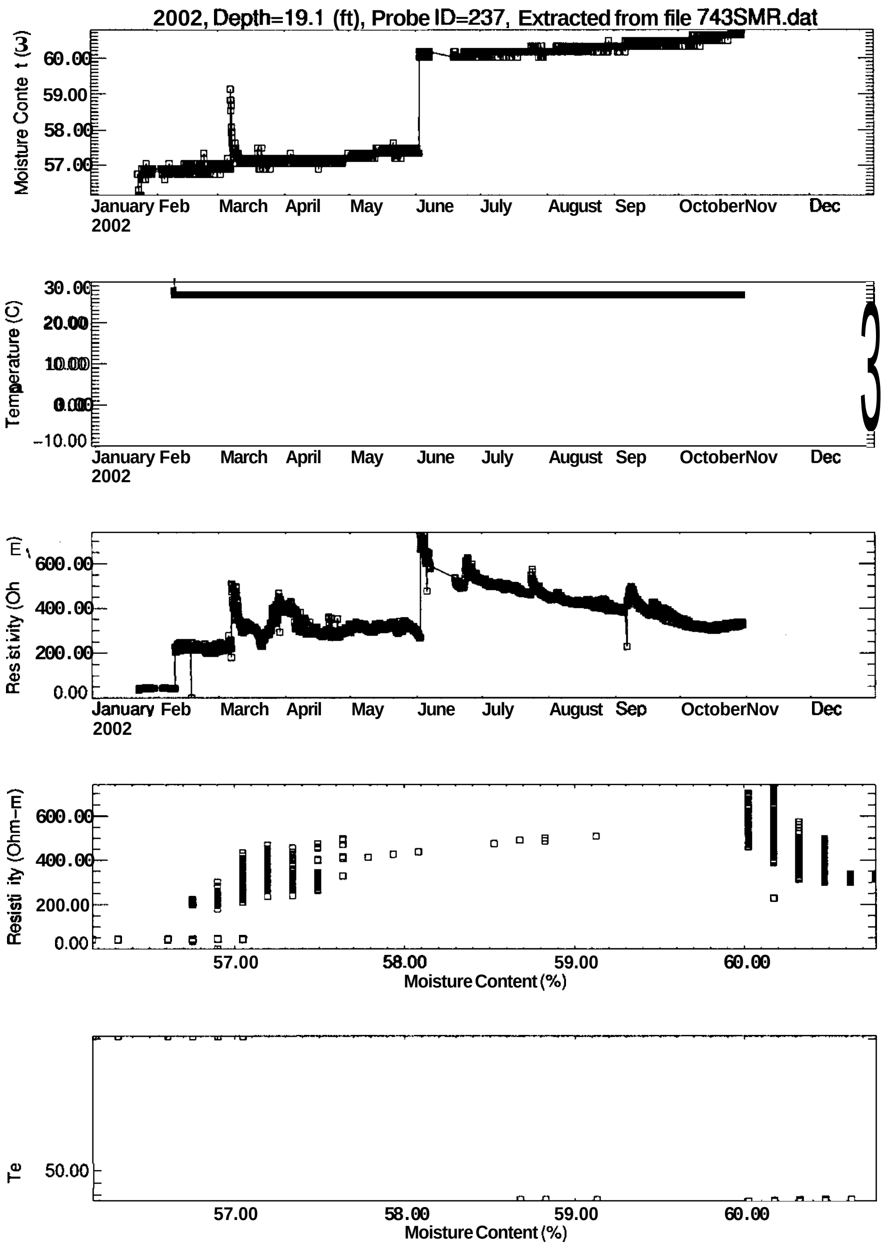

2002, Depth=11.5 (ft), Probe ID=268, Extracted from file 741SMR.dat
Moisture Content (%)
1.50
1.00
0.50
January 2002
Feb
March
April
May
June
July
August
Sep
October
Nov
Dec
Temperature (C)
30.00
20.00
10.00
0.00
-10.00
Resistivity (Ohm-m)
1200.00
1000.00
800.00
600.00
400.00
Moisture Content (%)
0.50
1.00
1.50
Temperature (C)
14.00
12.00
10.00
03-GA50310-126

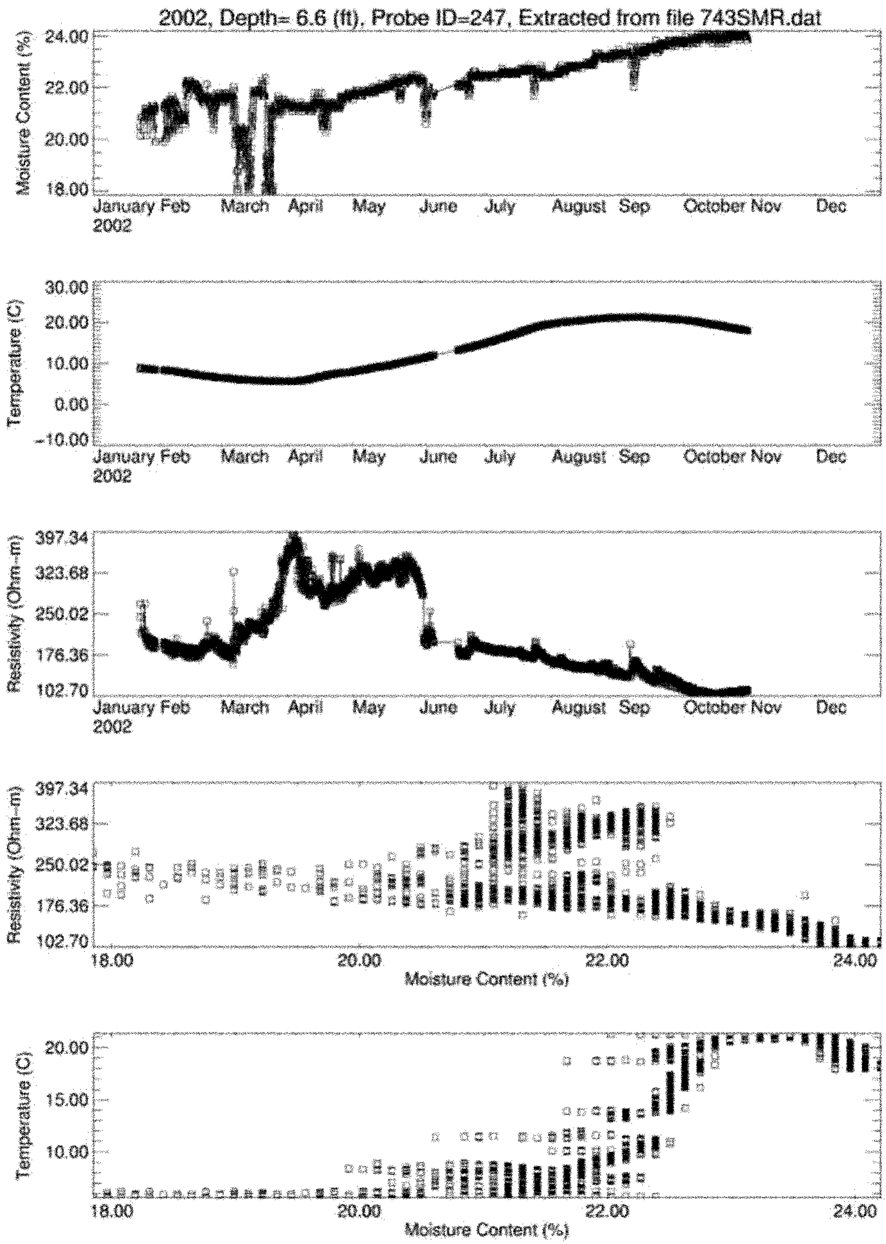


03-GA50310-127

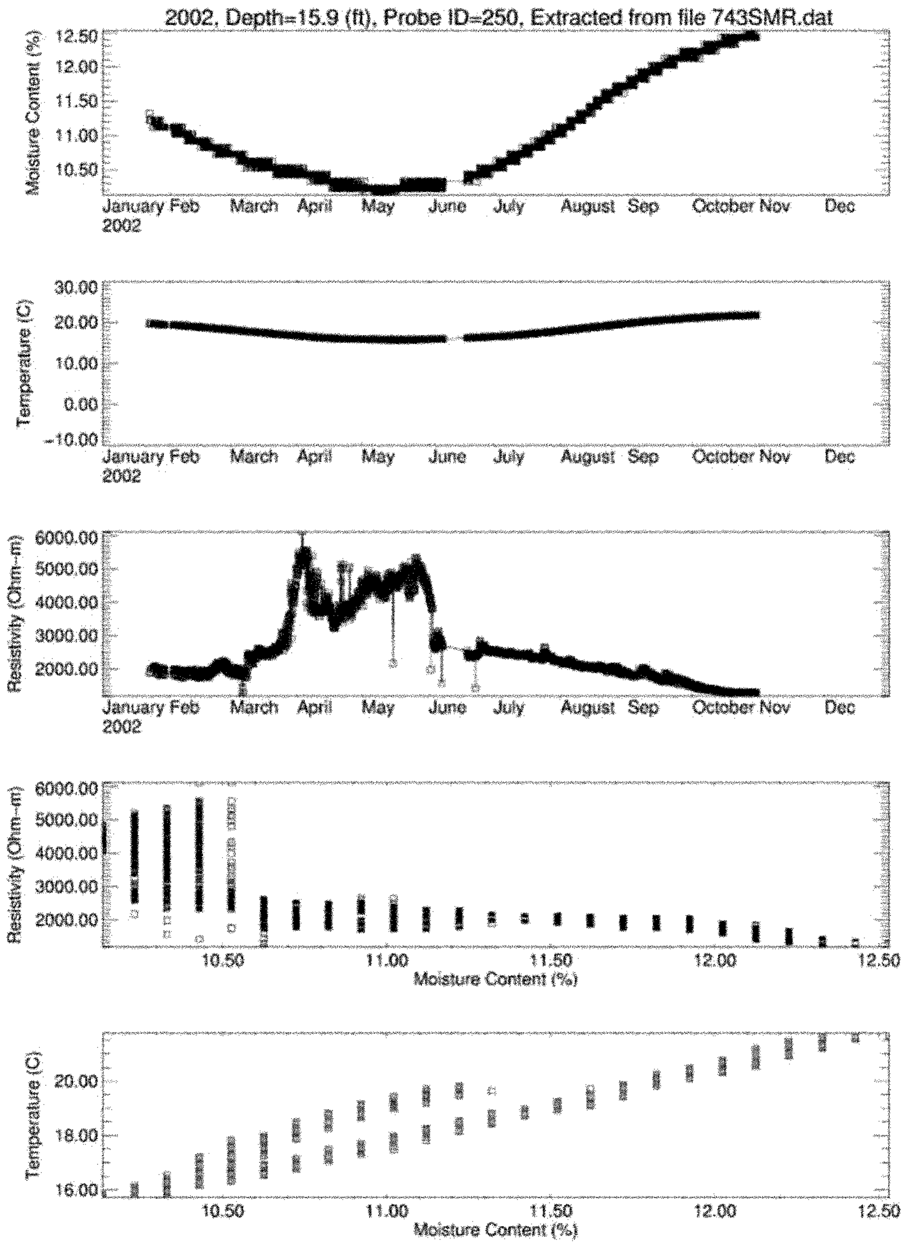


03-GA50310-128

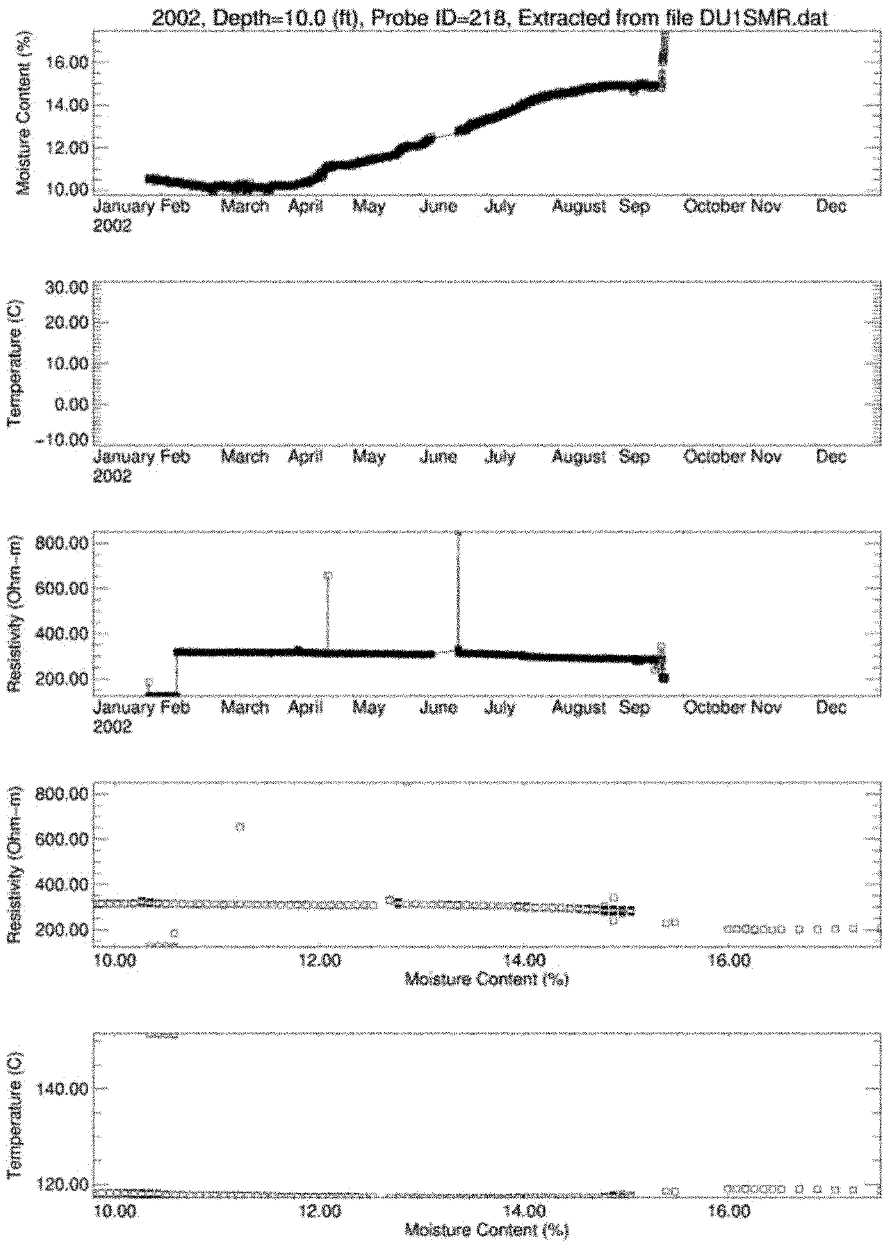

2002, Depth=19.1 (ft), Probe ID=237, Extracted from file 743SMR.dat
Moisture Content (%)
60.00
59.00
58.00
57.00
January Feb March April May June July August Sep OctoberNov Dec
2002
Temperature (C)
30.00
20.00
10.00
0.00
-10.00
January Feb March April May June July August Sep OctoberNov Dec
2002
Resistivity (Ohm-m)
600.00
400.00
200.00
0.00
January Feb March April May June July August Sep OctoberNov Dec
2002
Resistivity (Ohm-m)
600.00
400.00
200.00
0.00
57.00 58.00 59.00 60.00
Moisture Content (%)
Te
50.00
57.00 58.00 59.00 60.00
Moisture Content (%)



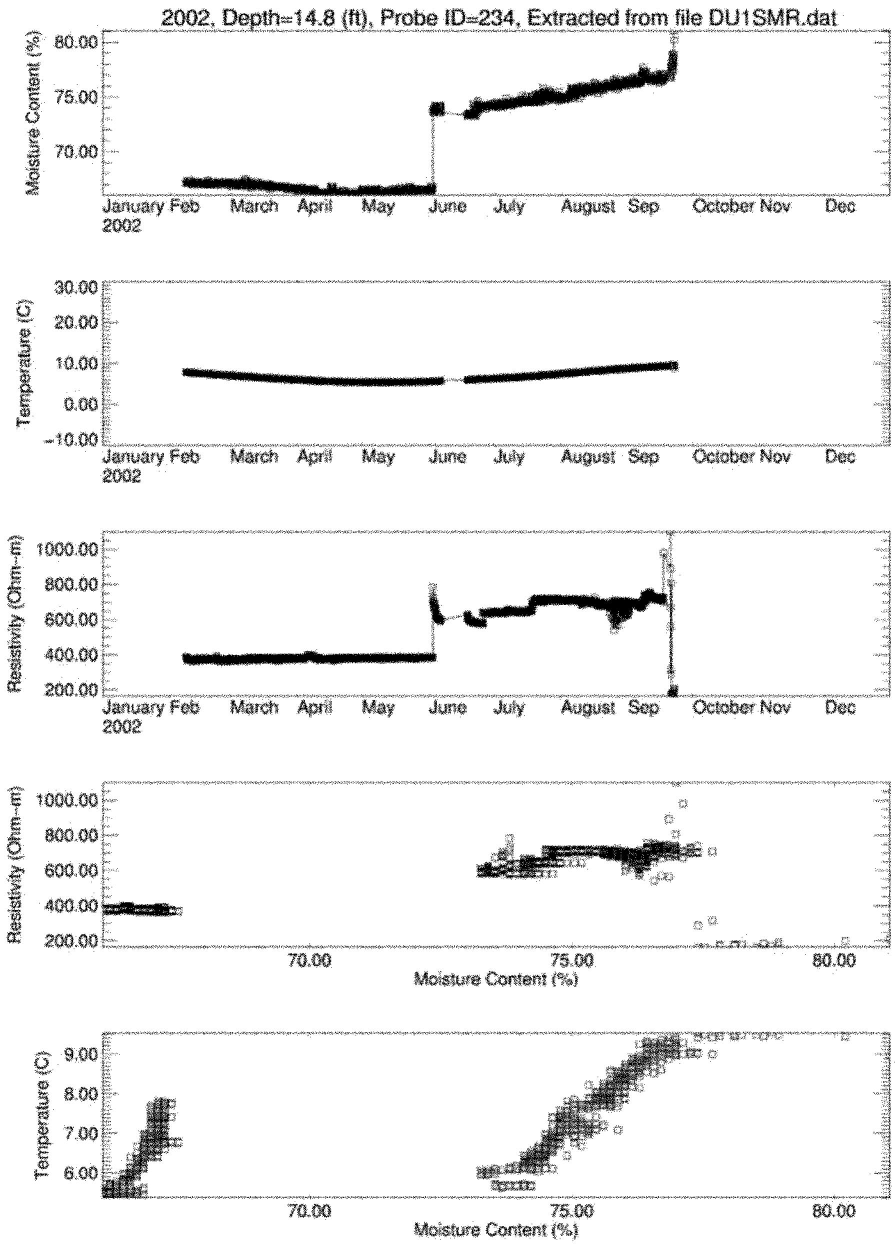
03-GA50310-130



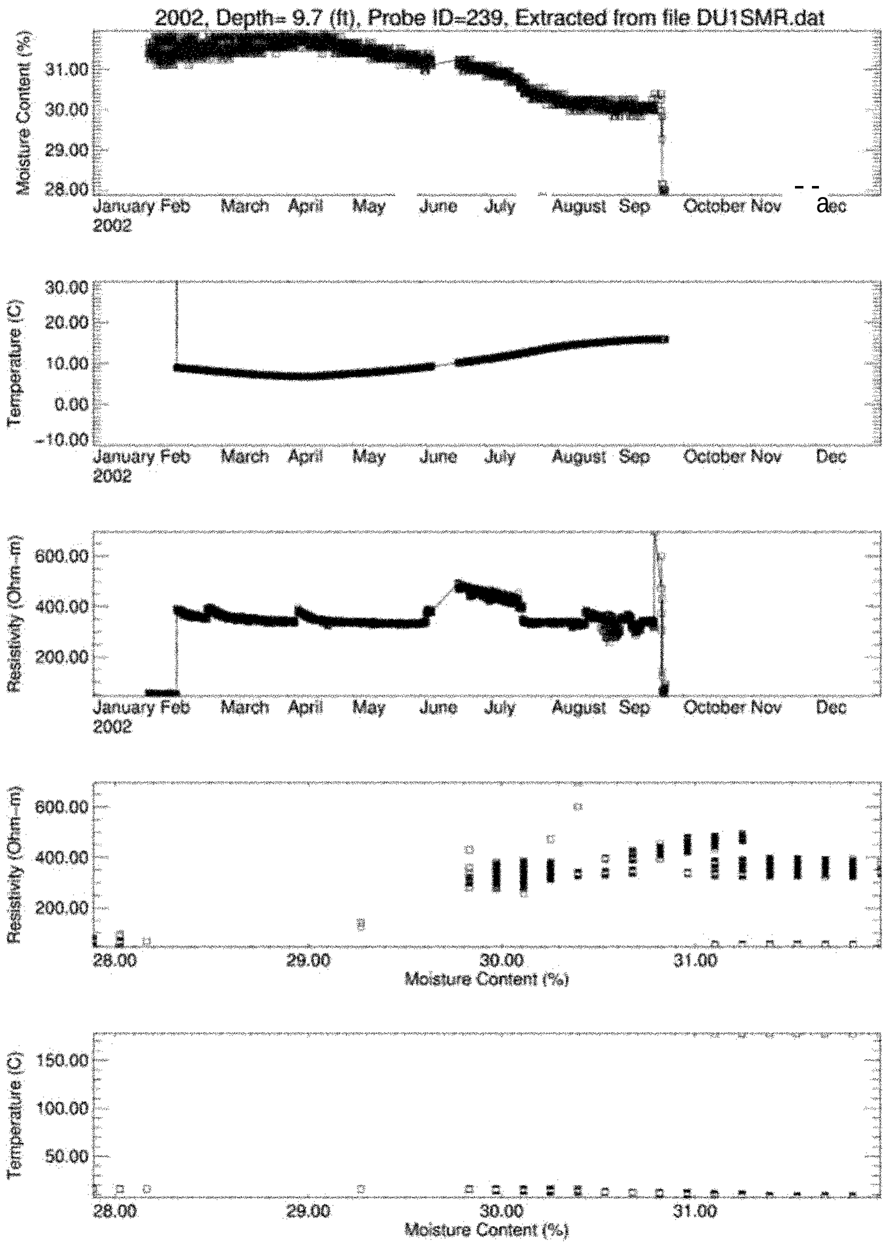
03-GA50310-131



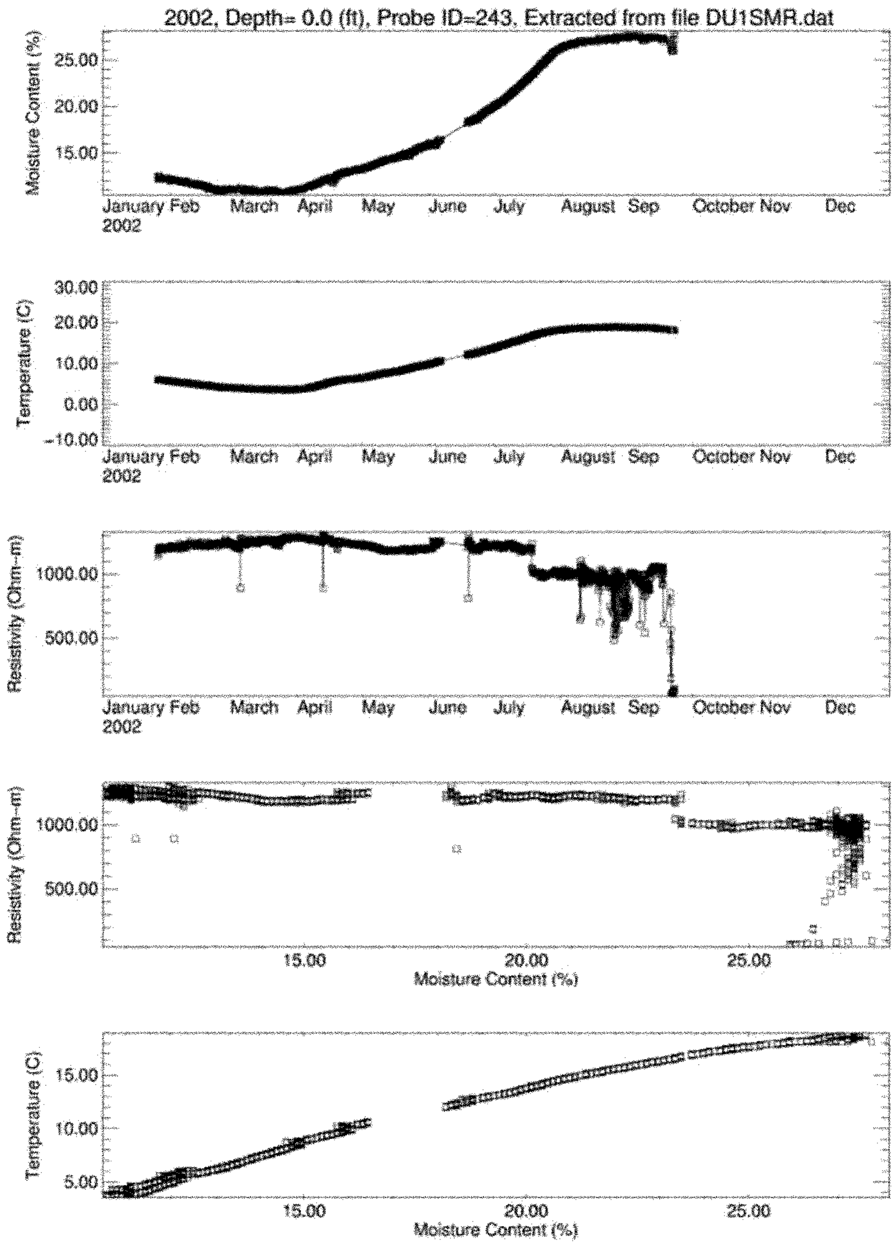
03-GA50310-132



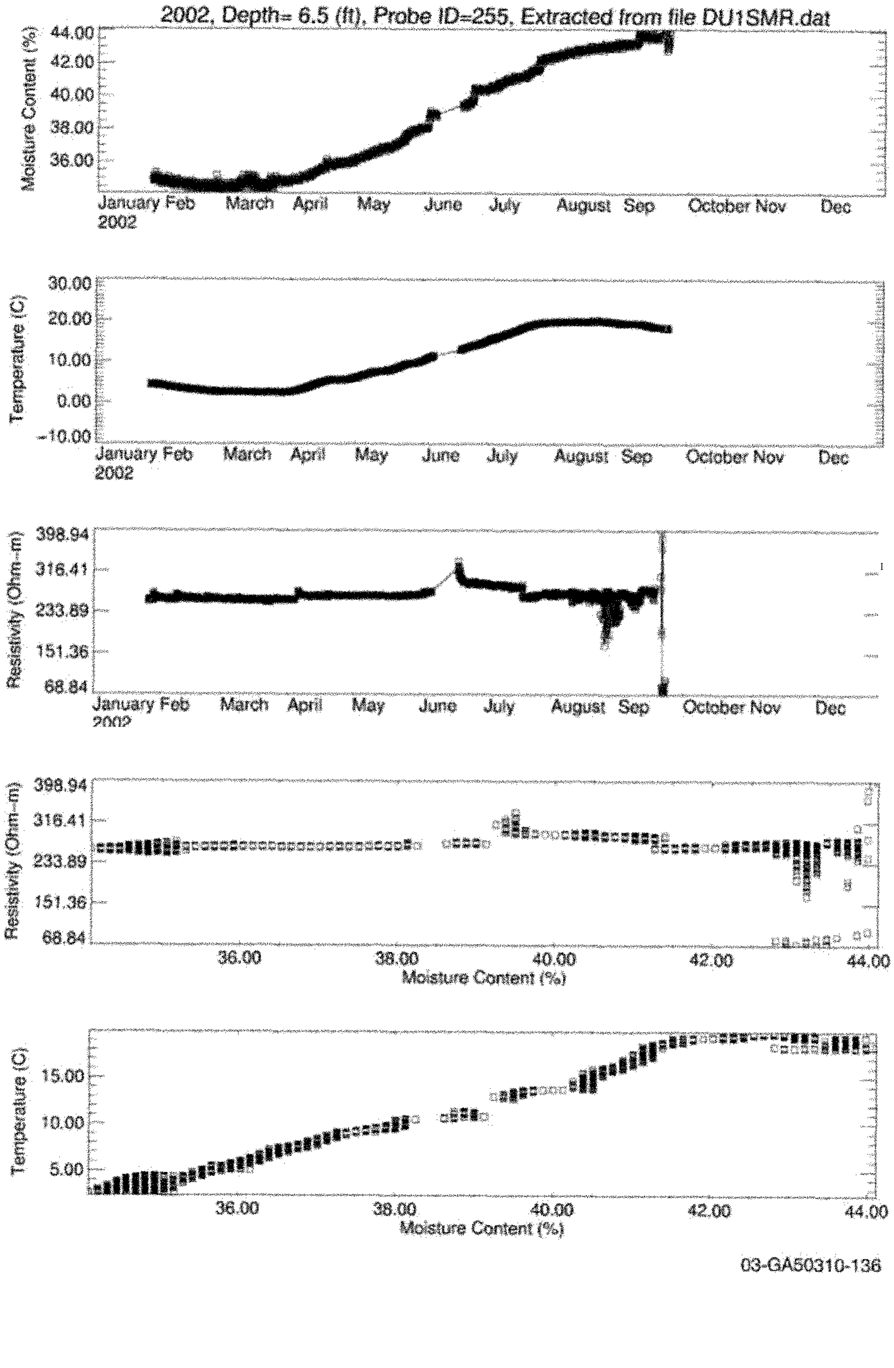
03-GA50310-133

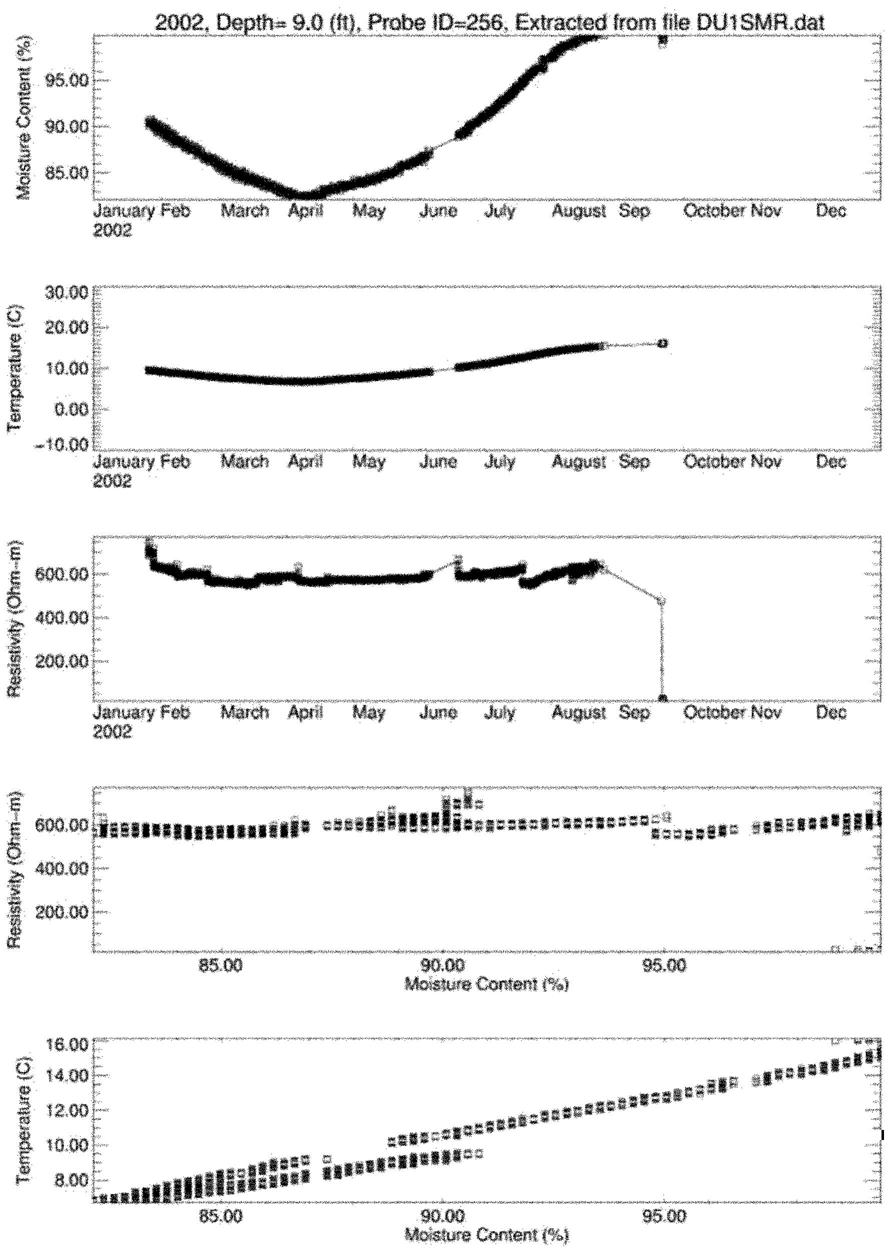


03-GA50310-134

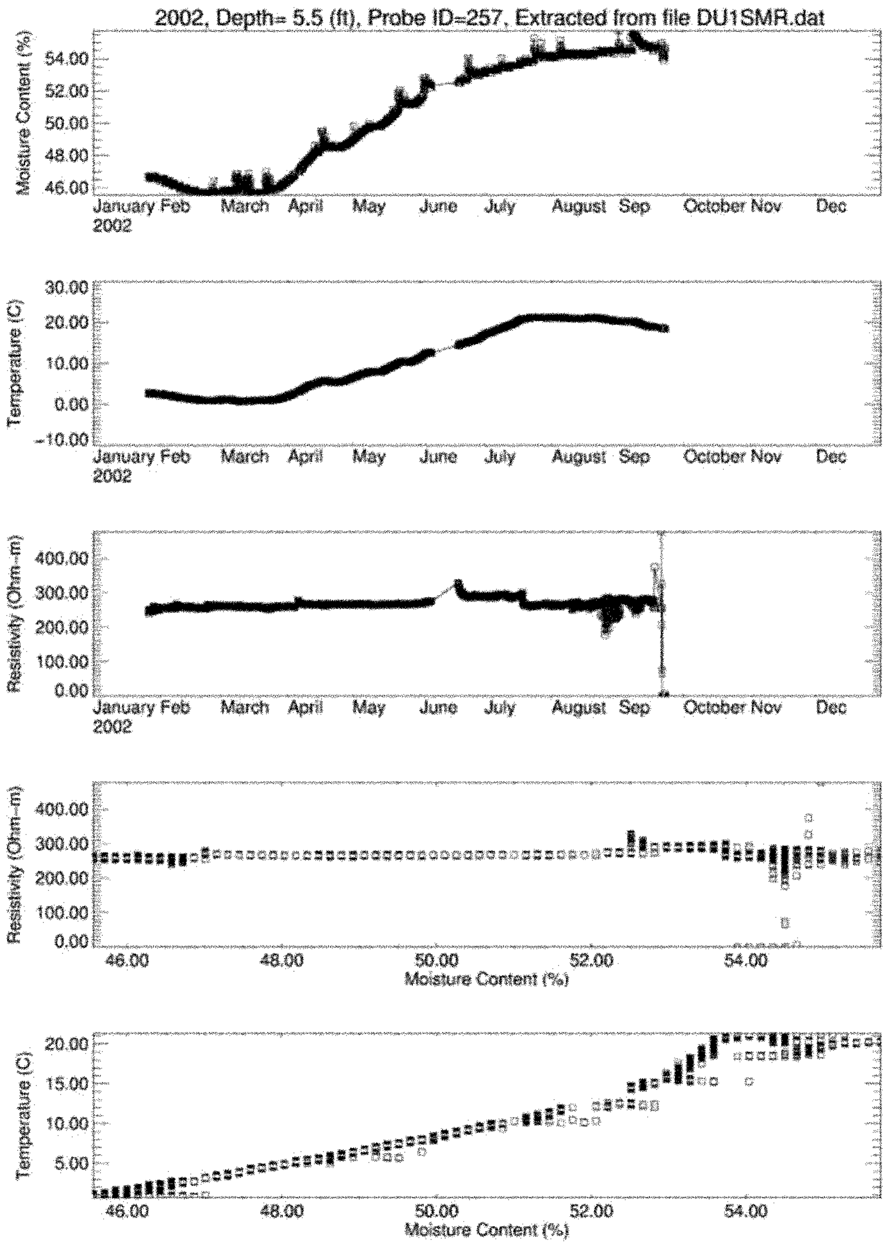


03-GA50310-135

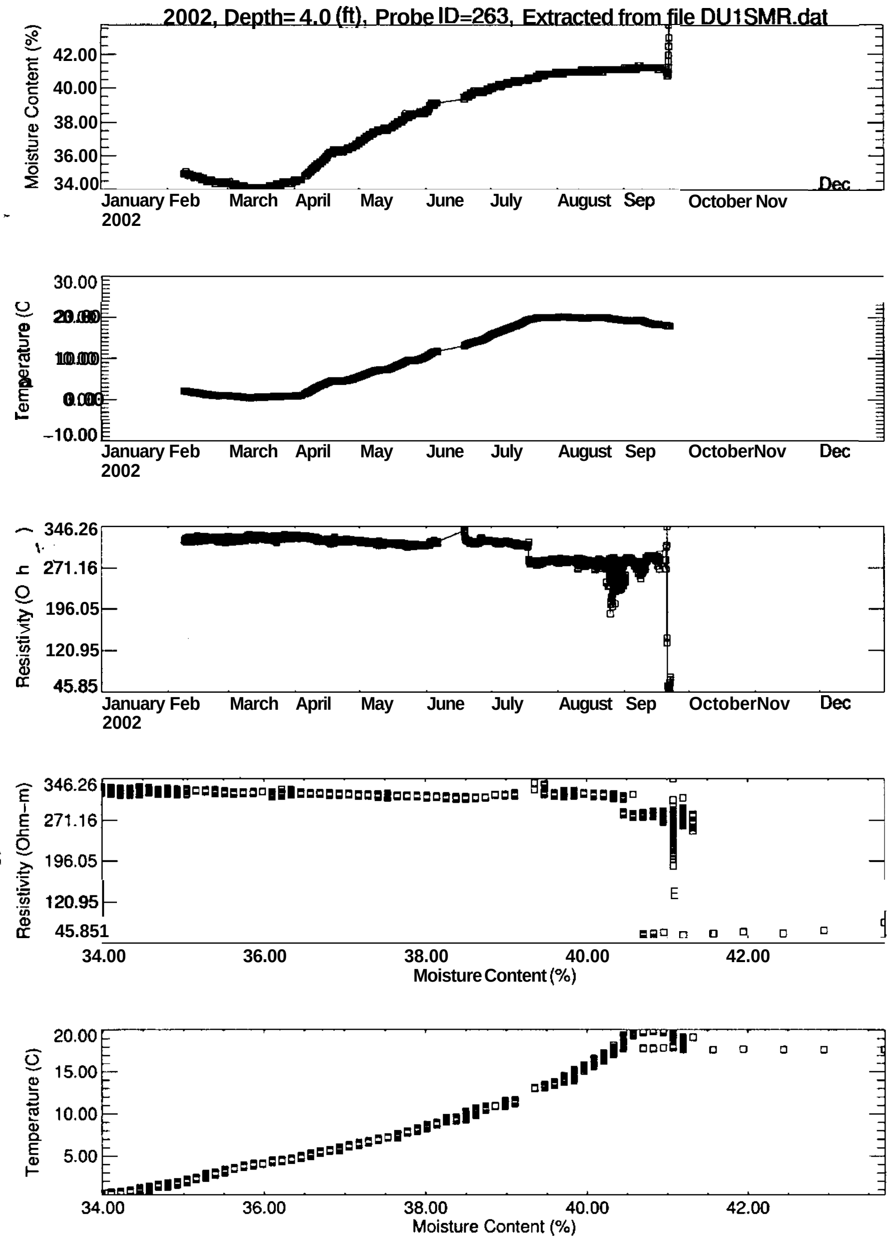

2002, Depth= 6.5 (ft), Probe ID=255, Extracted from file DU1SMR.dat
Moisture Content (%)
Temperature (C)
Resistivity (Ohm-m)
January 2002
Feb
March
April
May
June
July
August
Sep
October
Nov
Dec
Moisture Content (%)
03-GA50310-136

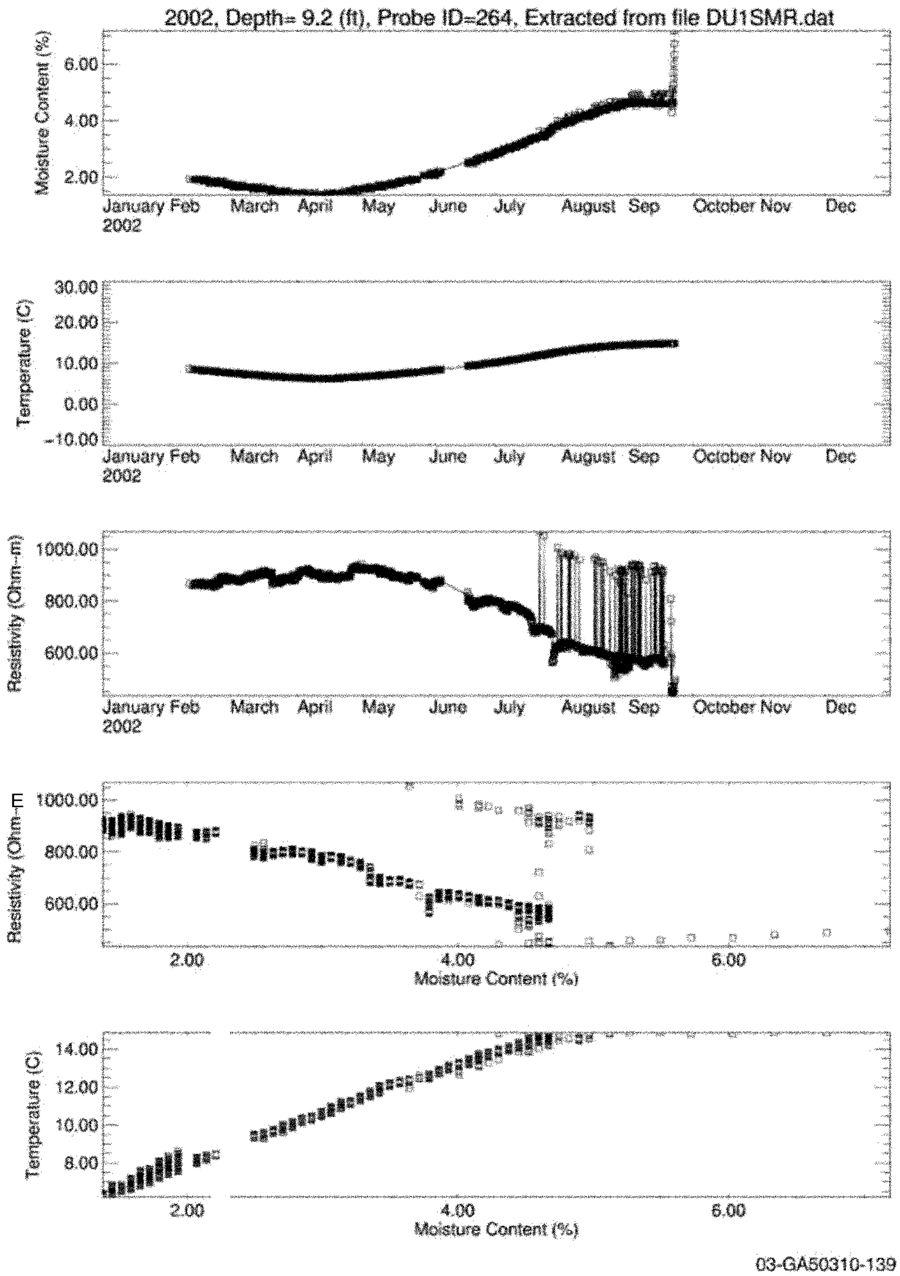


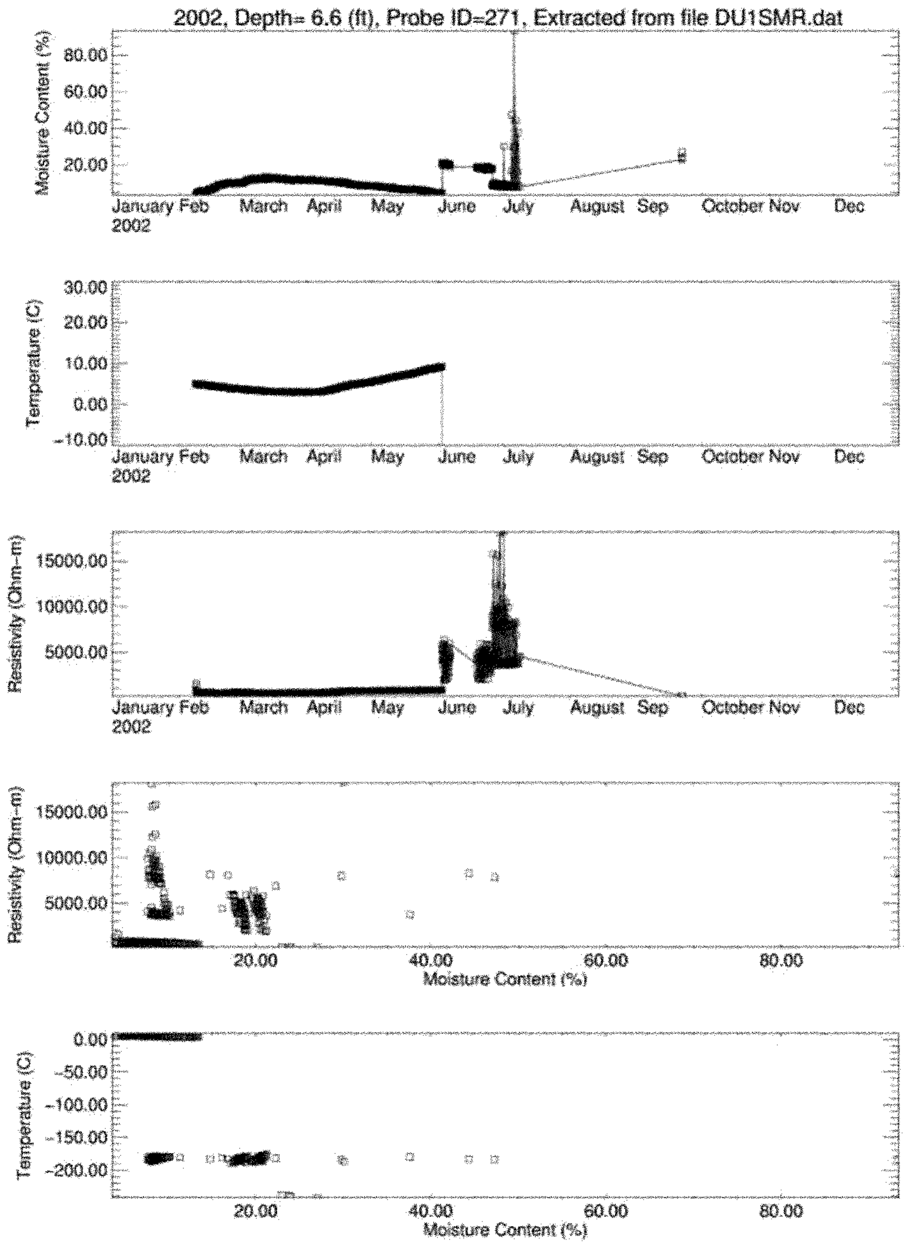
03-GA50310-137



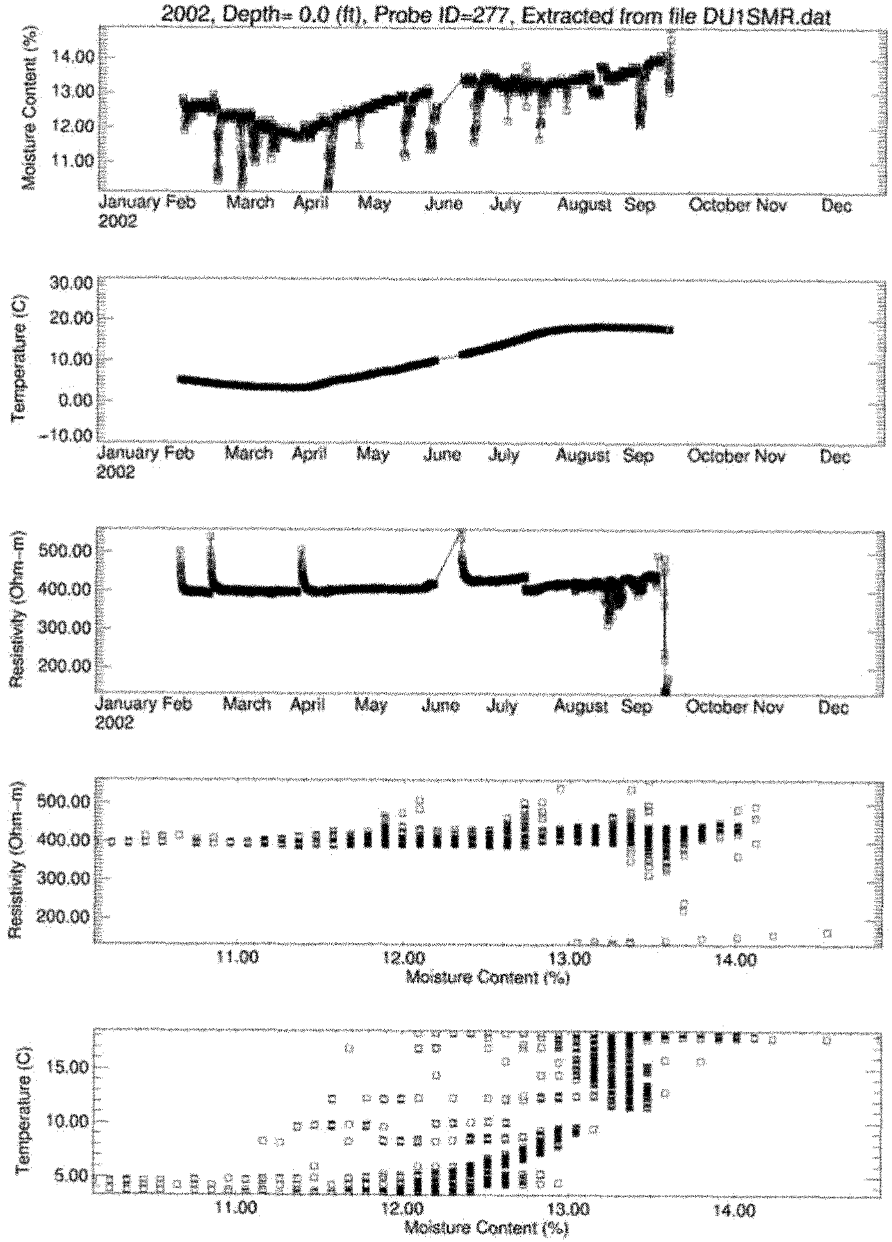
03-GA50310-138


2002, Depth= 4.0 (ft), Probe ID=263, Extracted from file DU1SMR.dat
Moisture Content (%)
42.00
40.00
38.00
36.00
34.00
January 2002
Feb
March
April
May
June
July
August
Sep
October
Nov
Dec
Temperature (C
30.00
20.00
10.00
0.00
-10.00
Resistivity (Ohm-m)
346.26
271.16
196.05
120.95
45.85
Moisture Content (%)
34.00
36.00
38.00
40.00
42.00
Temperature (C)
20.00
15.00
10.00
5.00

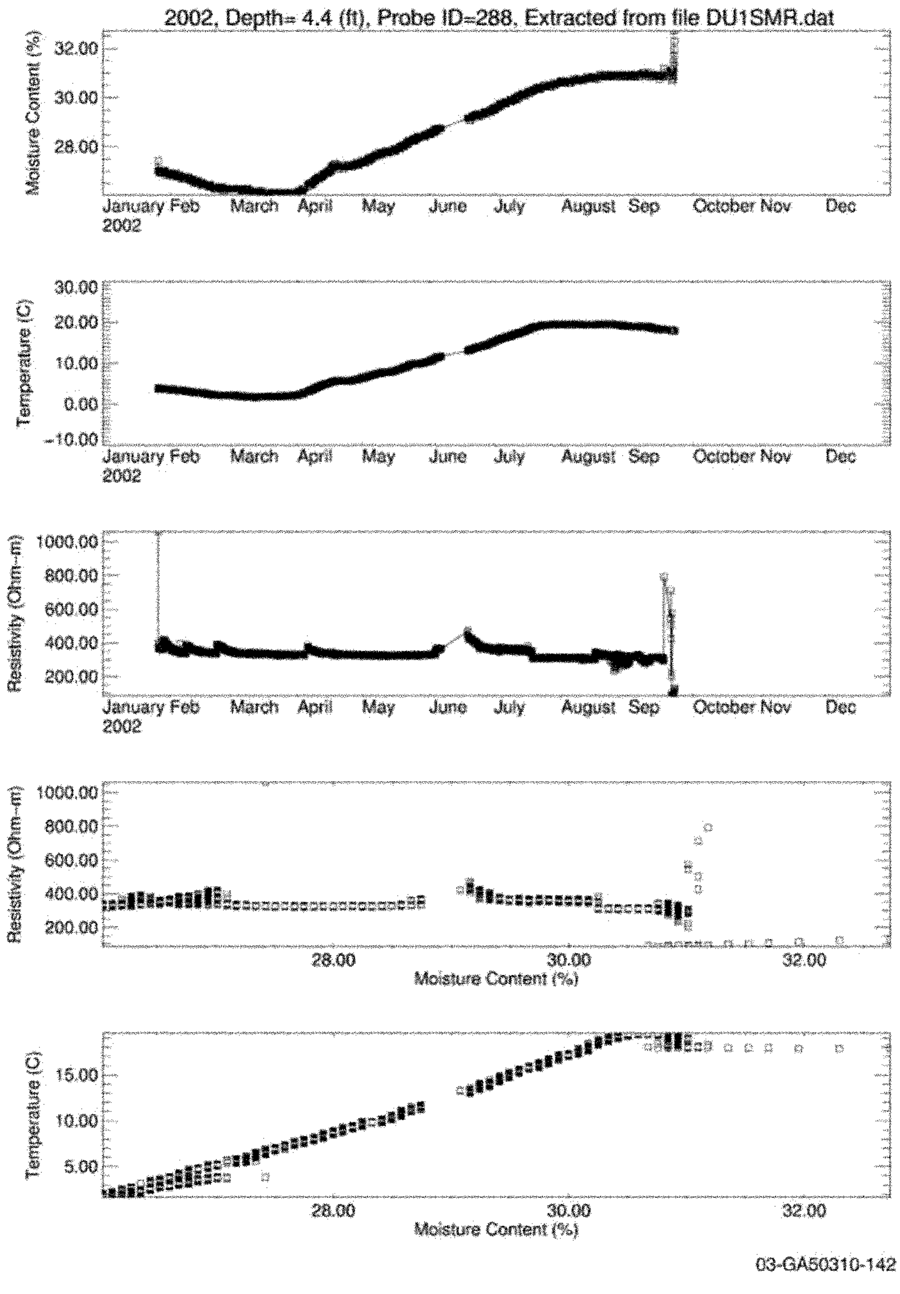

2002, Depth= 9.2 (ft), Probe ID=264, Extracted from file DU1SMR.dat
Moisture Content (%)
Temperature (C)
Resistivity (Ohm-m)
January 2002
Feb
March
April
May
June
July
August
Sep
October
Nov
Dec
Moisture Content (%)
03-GA50310-139

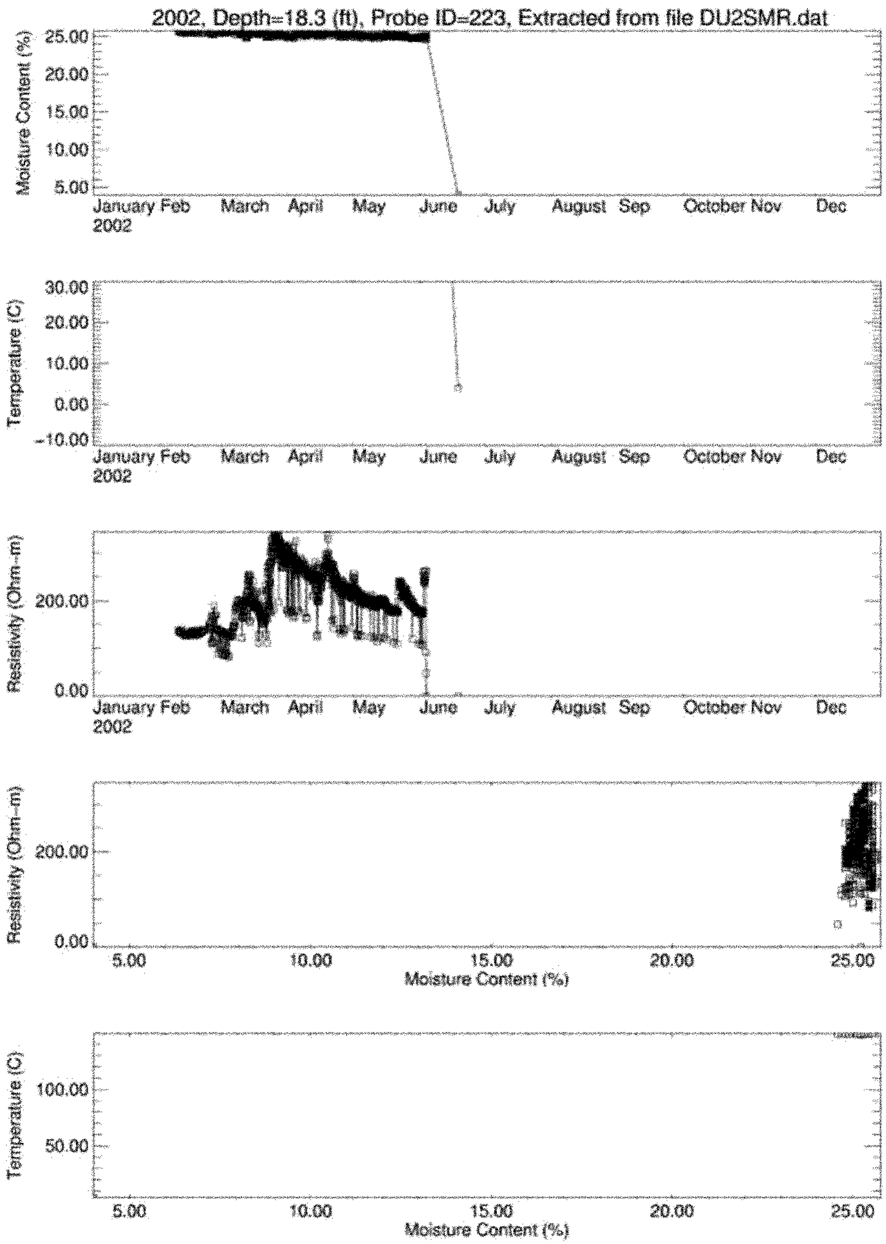


03-GA50310-140

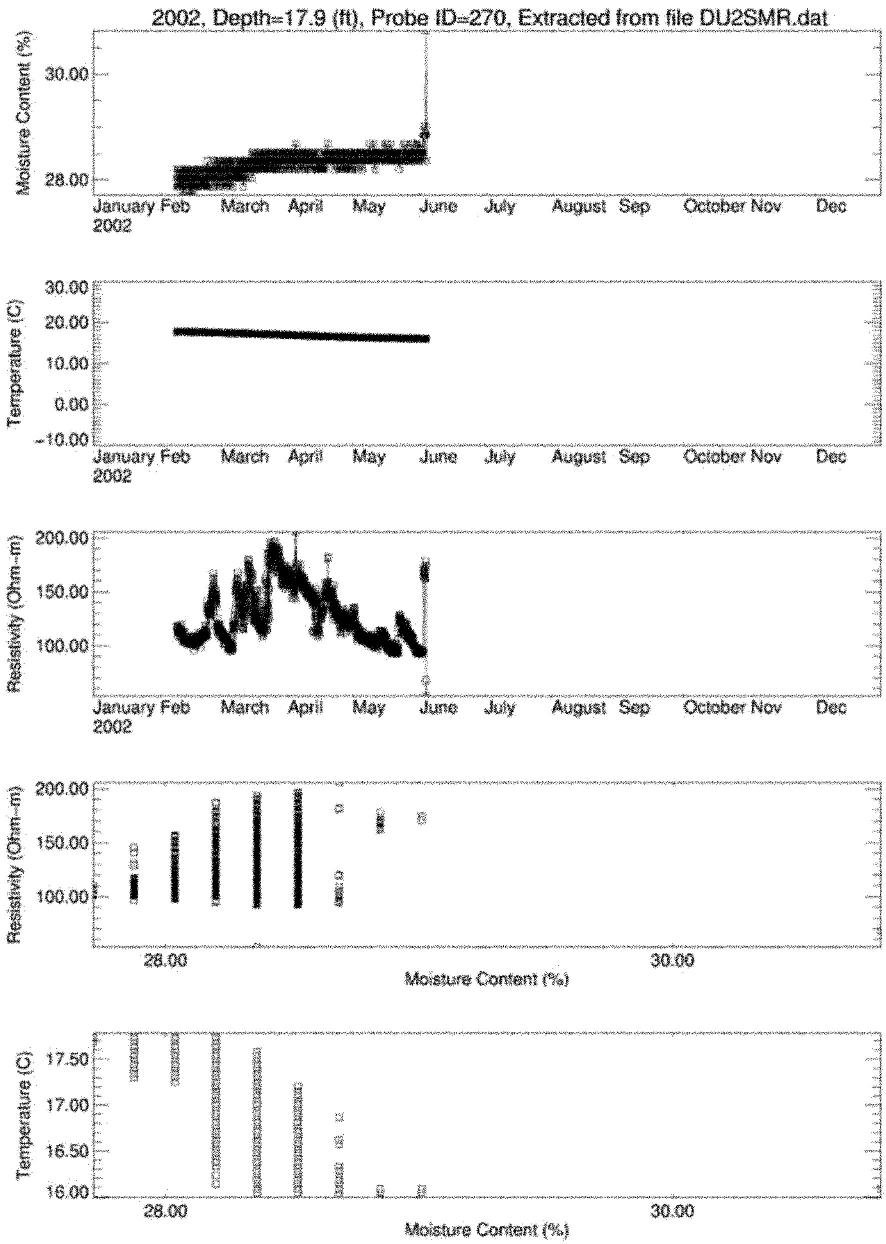


03-GA50310-141

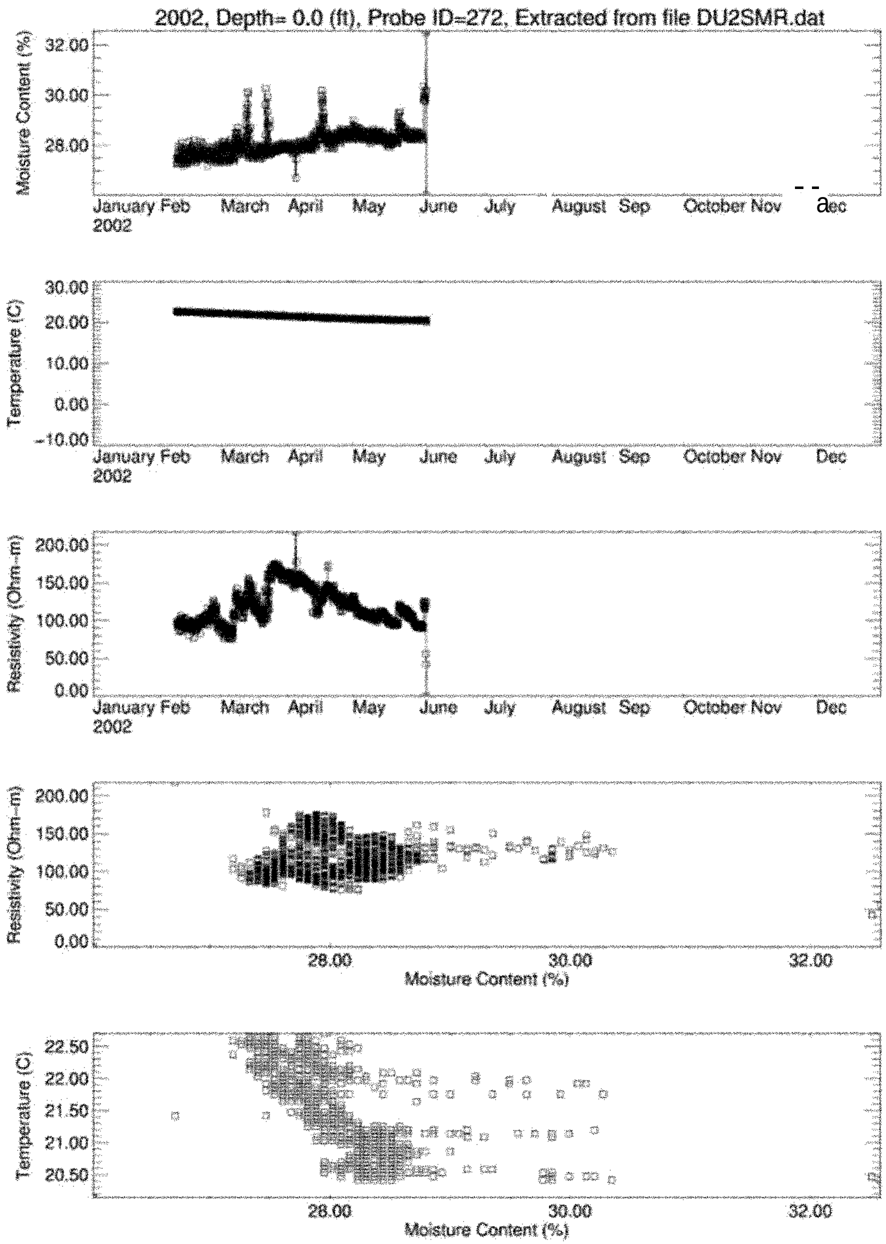

2002, Depth= 4.4 (ft), Probe ID=288, Extracted from file DU1SMR.dat
Moisture Content (%)
32.00
30.00
28.00
January 2002
Feb
March
April
May
June
July
August
Sep
October
Nov
Dec
Temperature (C)
30.00
20.00
10.00
0.00
-10.00
Resistivity (Ohm-m)
1000.00
800.00
600.00
400.00
200.00
Moisture Content (%)
28.00
30.00
32.00
Temperature (C)
15.00
10.00
5.00
03-GA50310-142



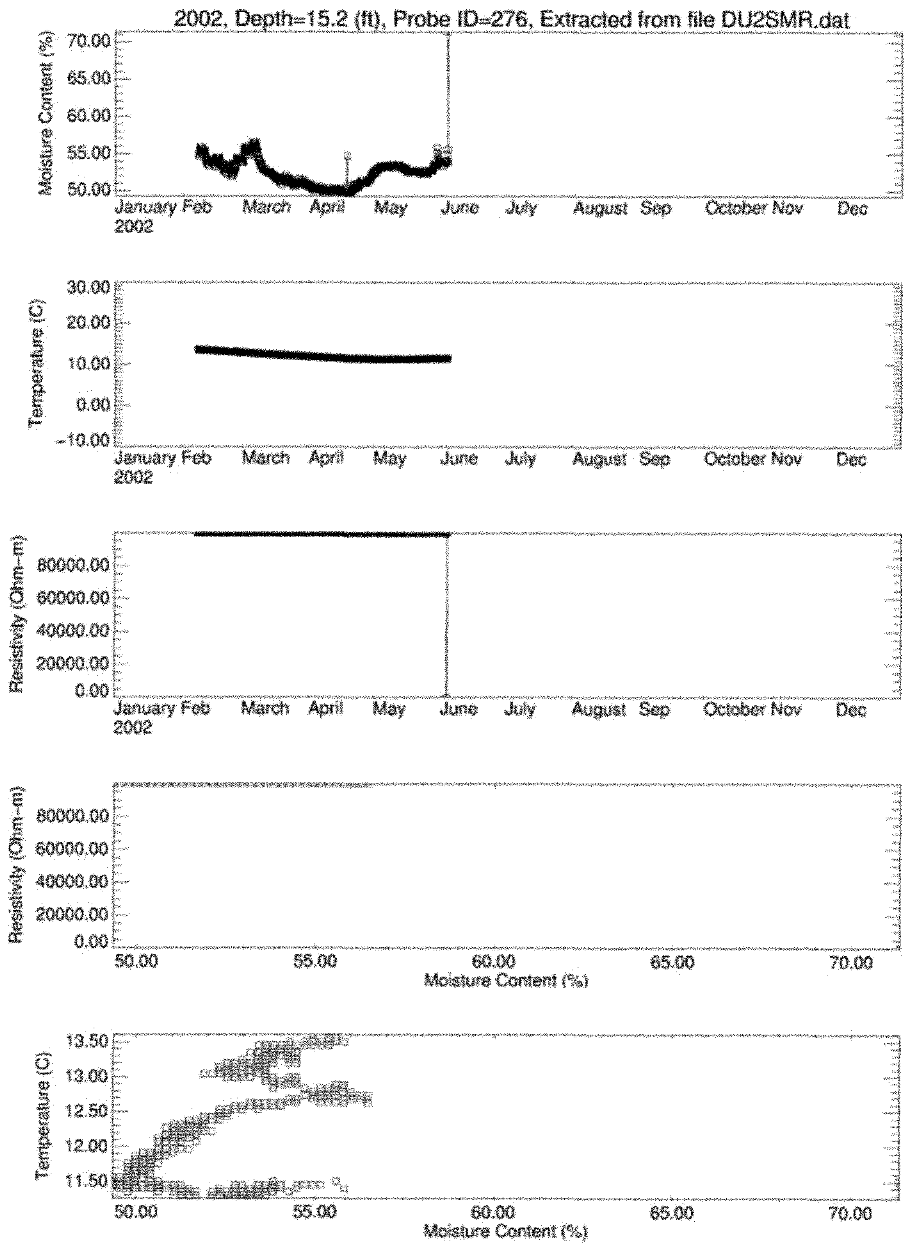
03-GA50310-143



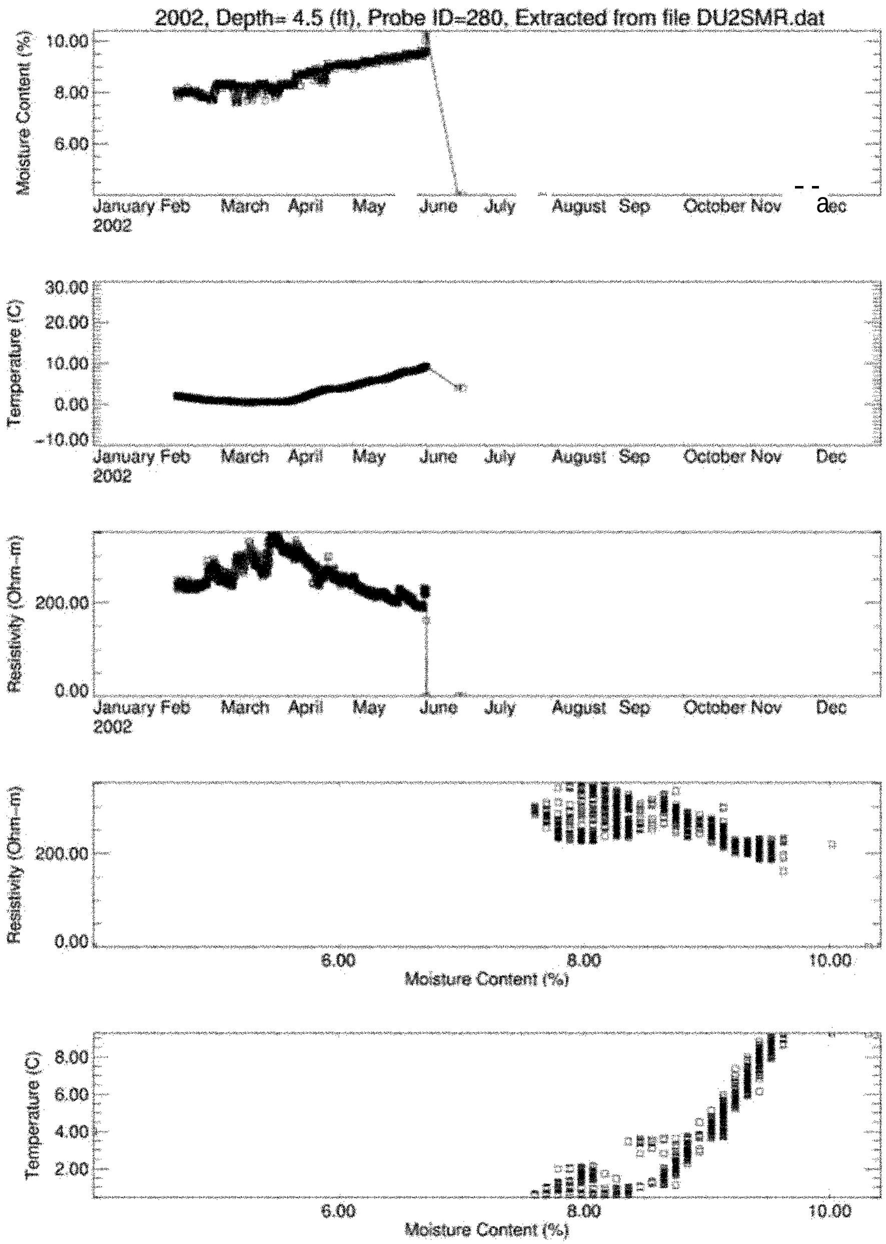
03-GA50310-144



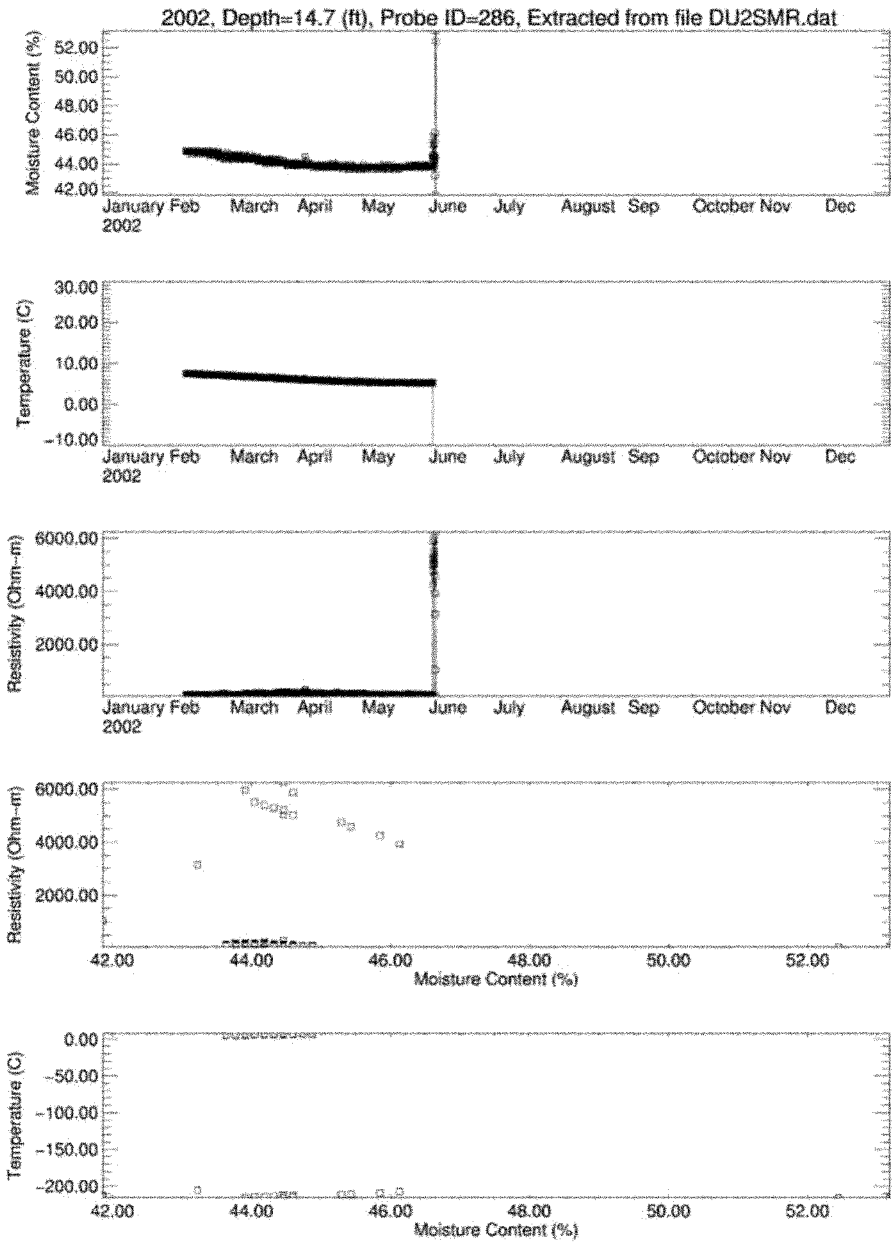
03-GA50310-145



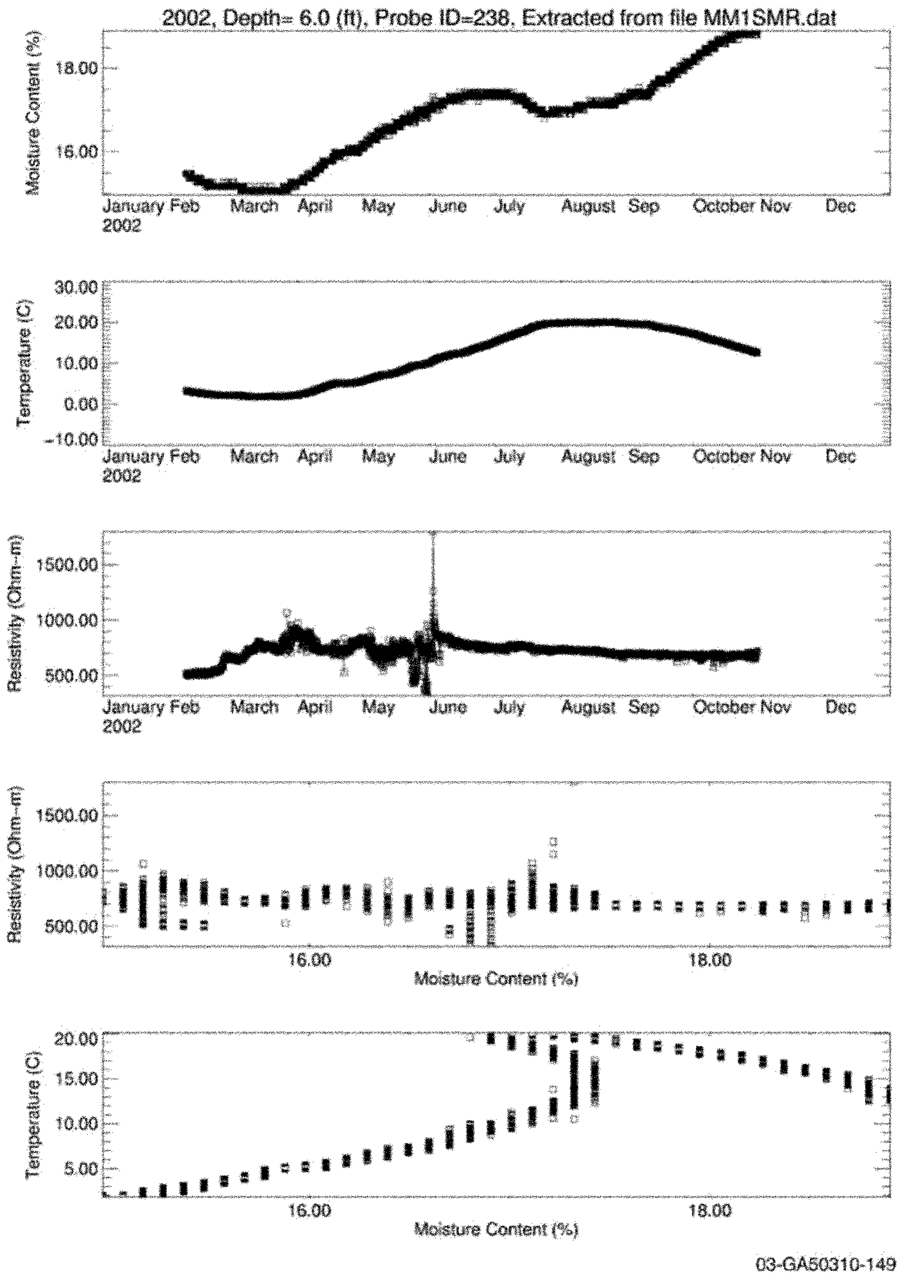
03-GA50310-146

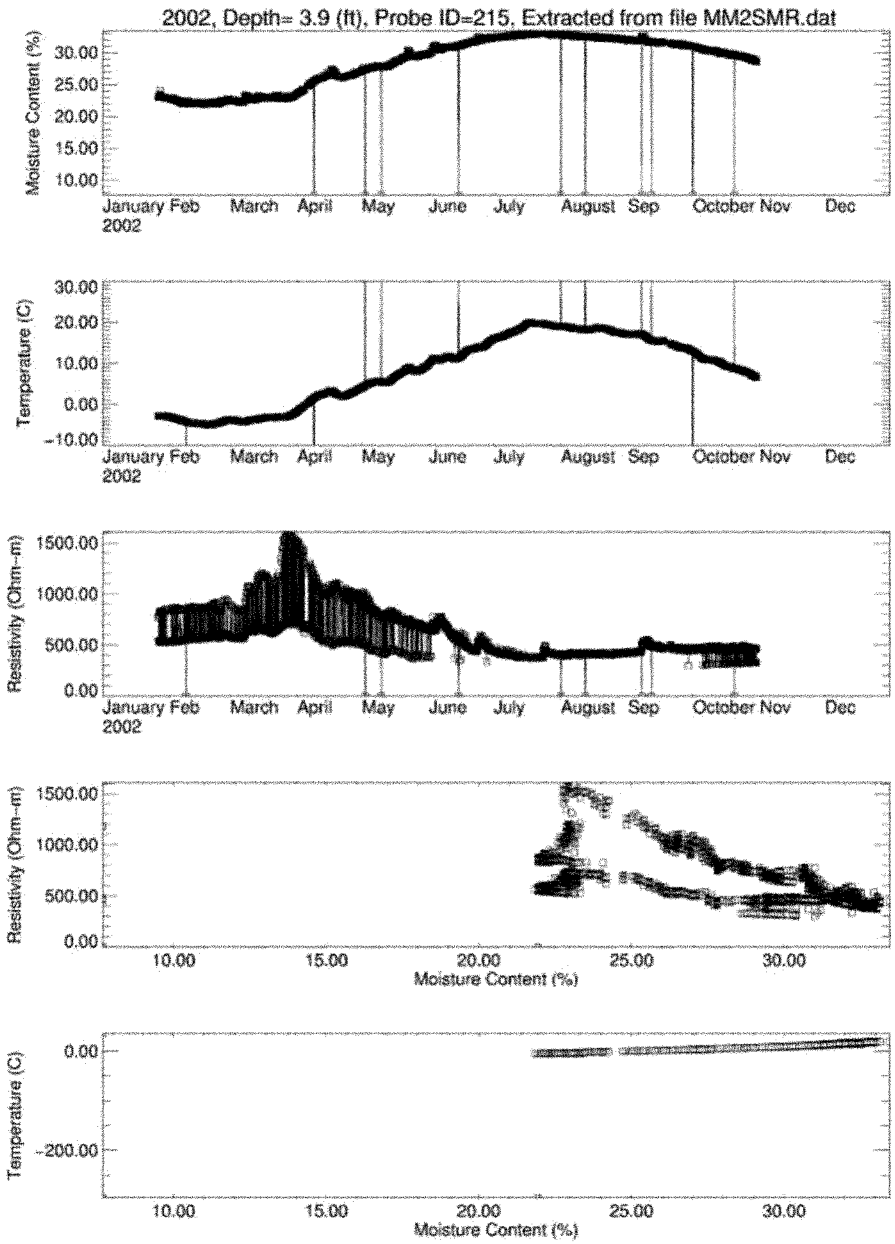


03-GA50310-147

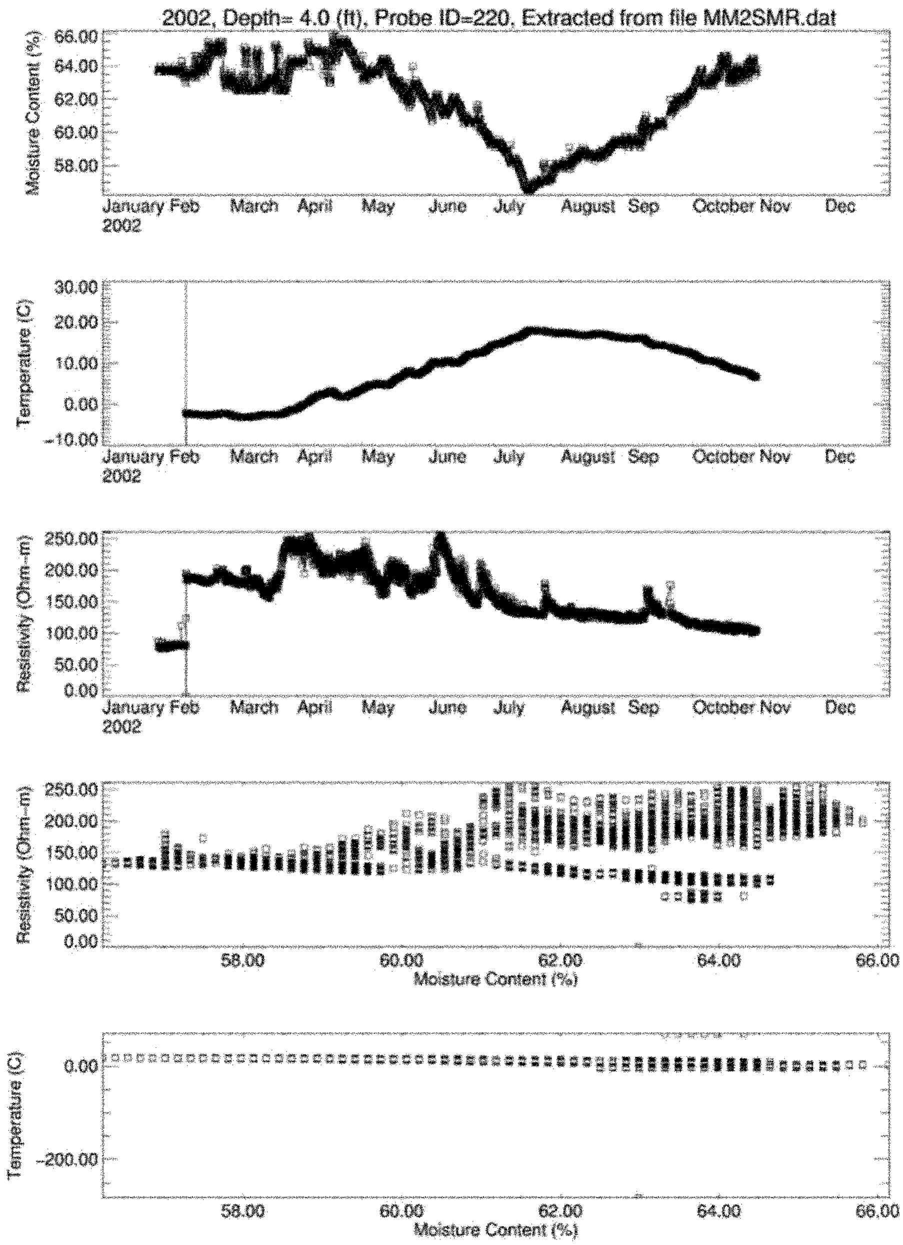


03-GA50310-148

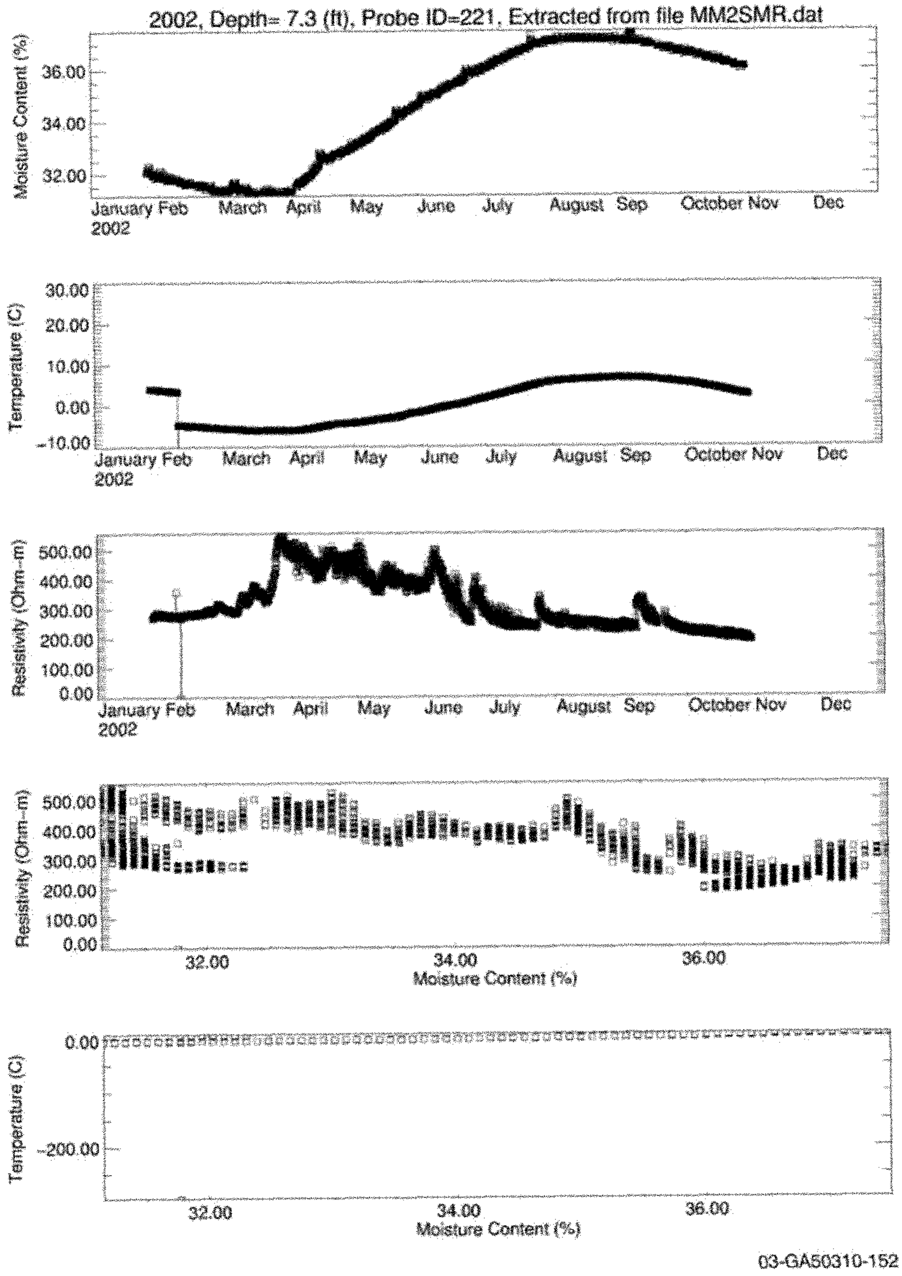

2002, Depth= 6.0 (ft), Probe ID=238, Extracted from file MM1SMR.dat
Moisture Content (%)
Temperature (C)
Resistivity (Ohm-m)
January 2002
Feb
March
April
May
June
July
August
Sep
October
Nov
Dec
Moisture Content (%)
03-GA50310-149

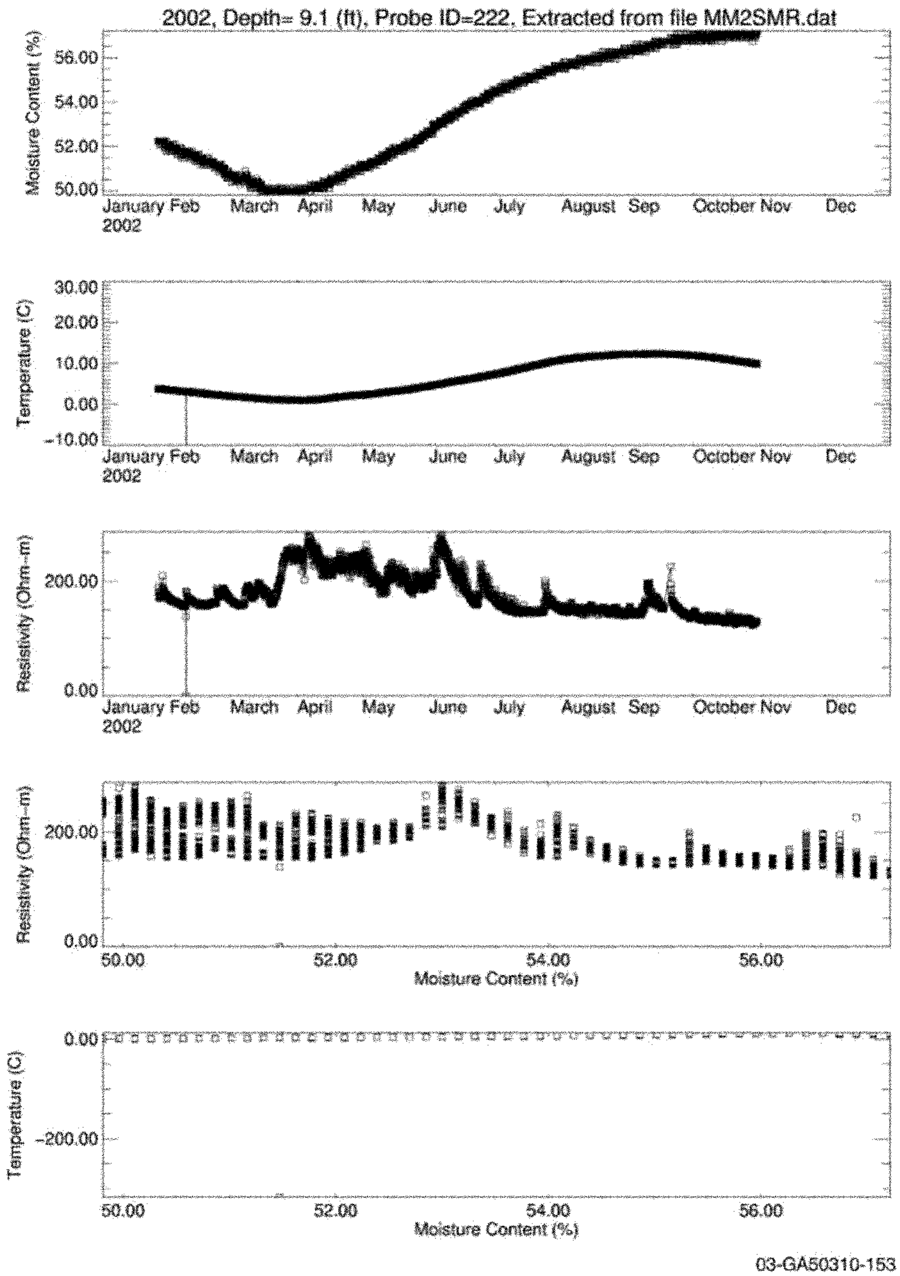


03-GA50310-150

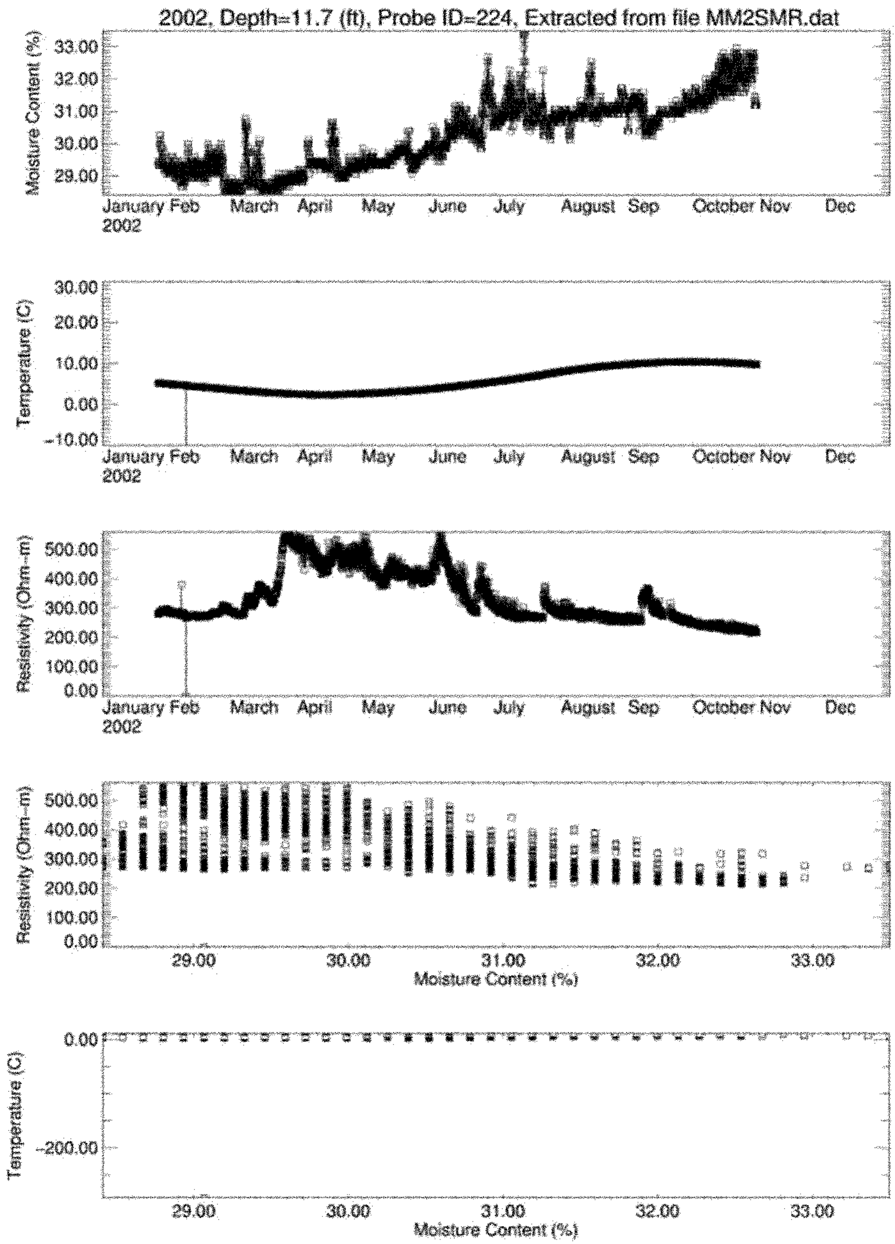


03-GA50310-151

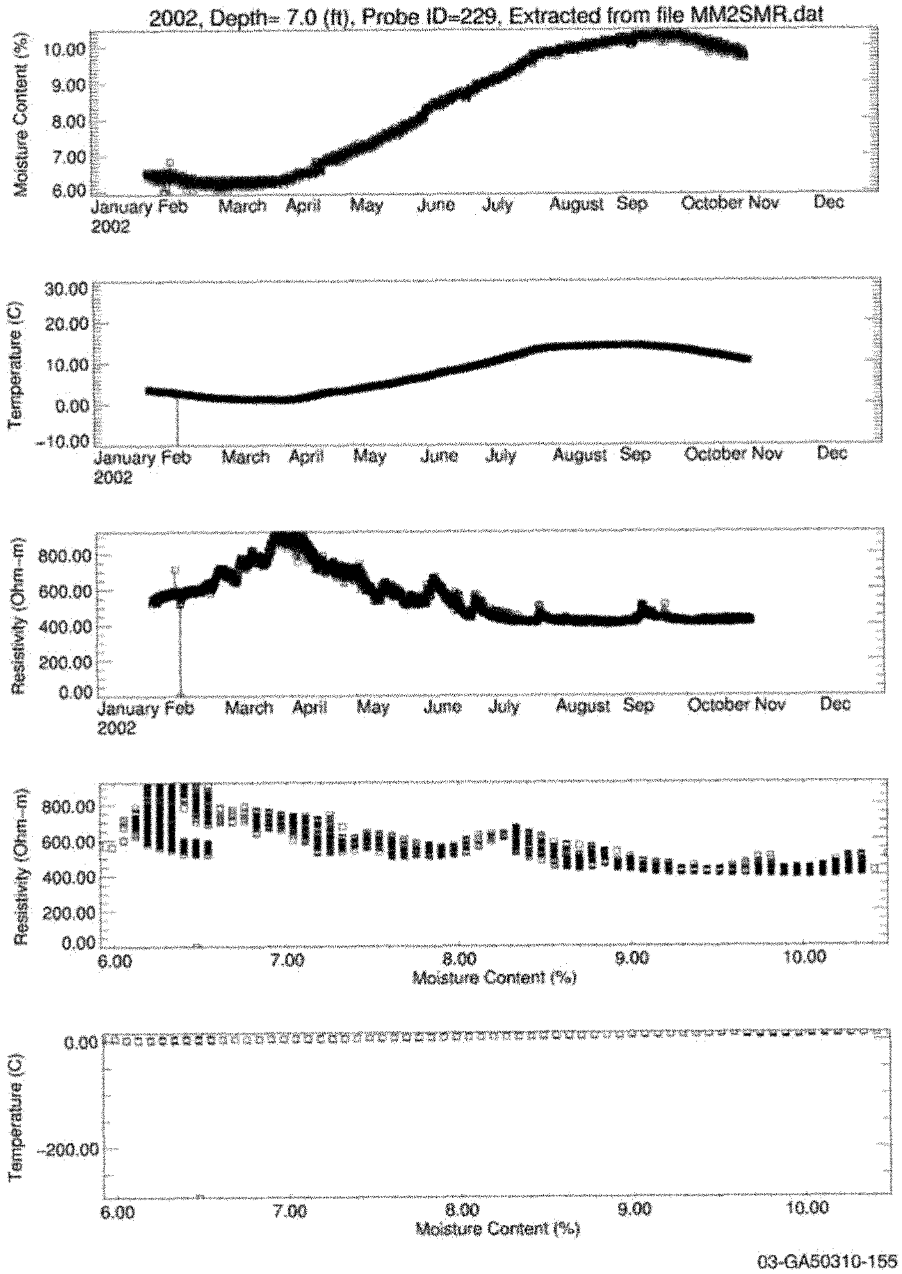

2002, Depth= 7.3 (ft), Probe ID=221, Extracted from file MM2SMR.dat
Moisture Content (%)
Temperature (C)
Resistivity (Ohm-m)
January 2002
Feb
March
April
May
June
July
August
Sep
October
Nov
Dec
Moisture Content (%)
03-GA50310-152



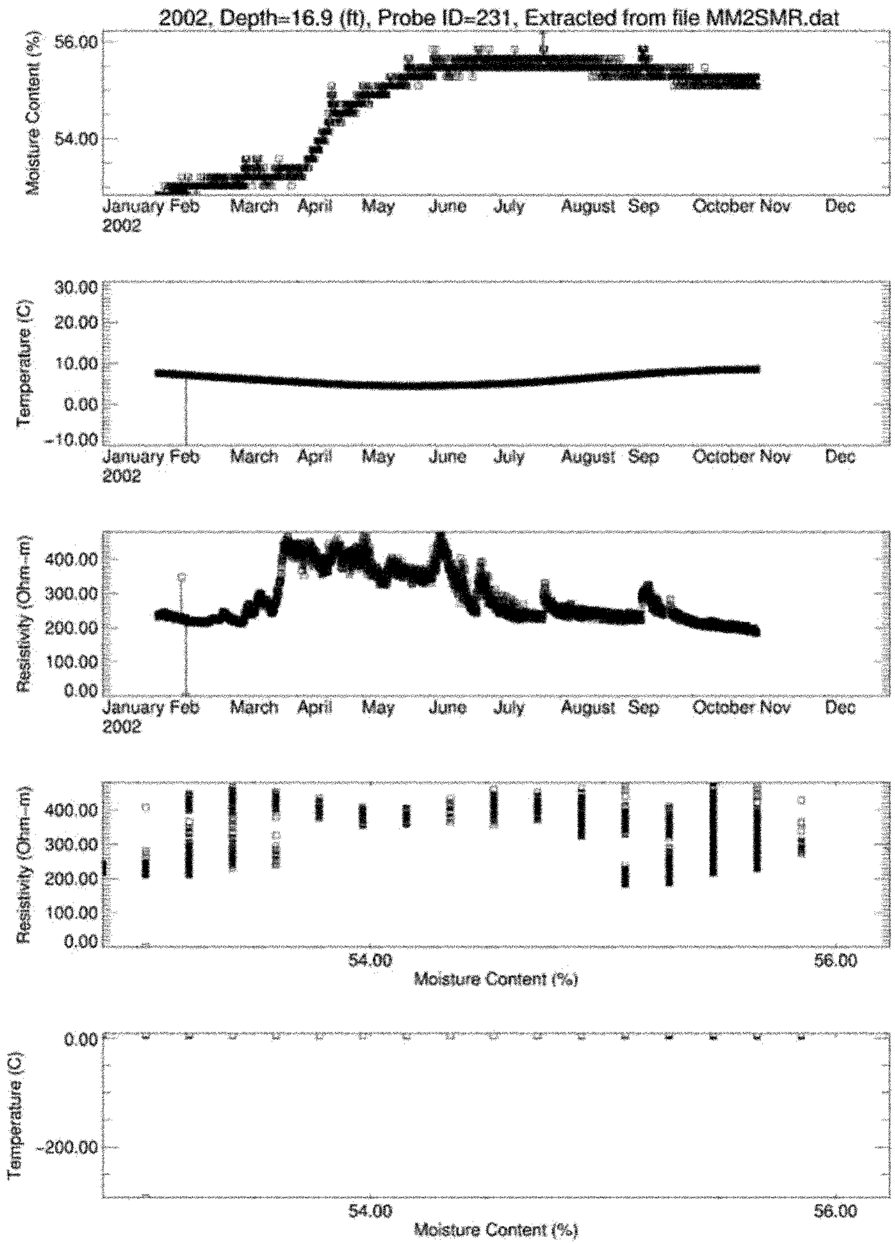
2002, Depth= 9.1 (ft), Probe ID=222, Extracted from file MM2SMR.dat
Moisture Content (%)
56.00
54.00
52.00
50.00
January Feb March April May June July August Sep October Nov Dec
2002
Temperature (C)
30.00
20.00
10.00
0.00
-10.00
Resistivity (Ohm-m)
200.00
0.00
Moisture Content (%)
50.00
52.00
54.00
56.00
-200.00
03-GA50310-153



03-GA50310-154

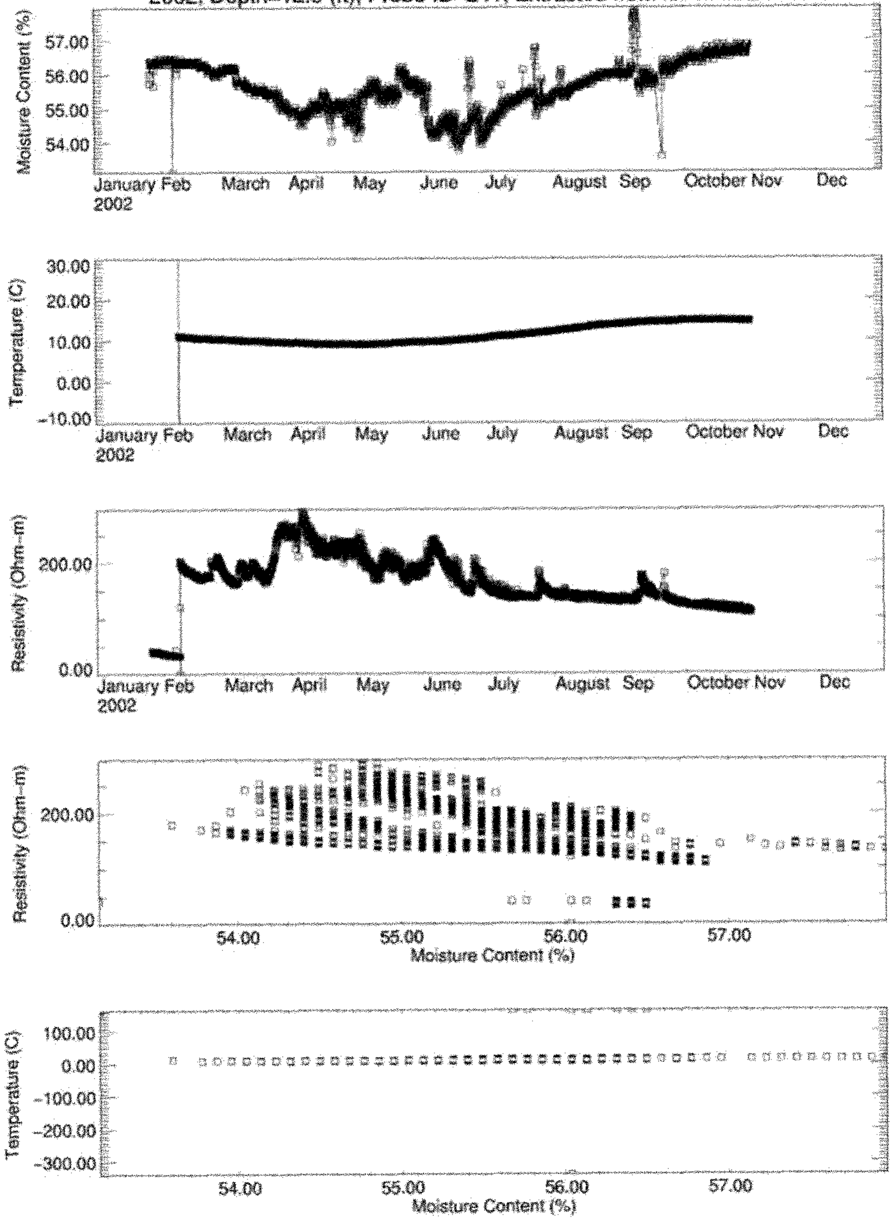


2002, Depth= 7.0 (ft), Probe ID=229, Extracted from file MM2SMR.dat
Moisture Content (%)
10.00
9.00
8.00
7.00
6.00
January 2002
Feb
March
April
May
June
July
August
Sep
October
Nov
Dec
Temperature (C)
30.00
20.00
10.00
0.00
-10.00
Resistivity (Ohm-m)
800.00
600.00
400.00
200.00
0.00
Moisture Content (%)
6.00
7.00
8.00
9.00
10.00
-200.00
03-GA50310-155

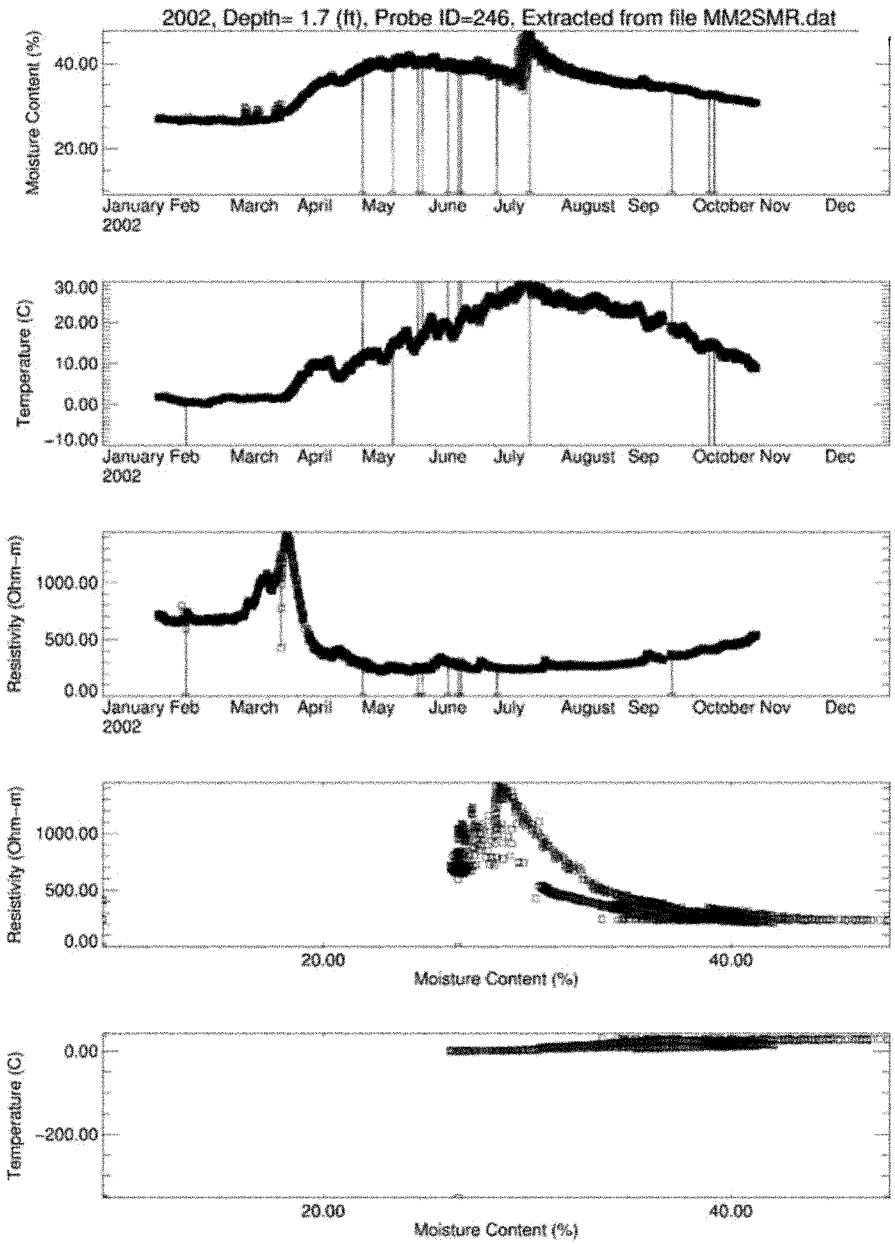


03-GA50310-156

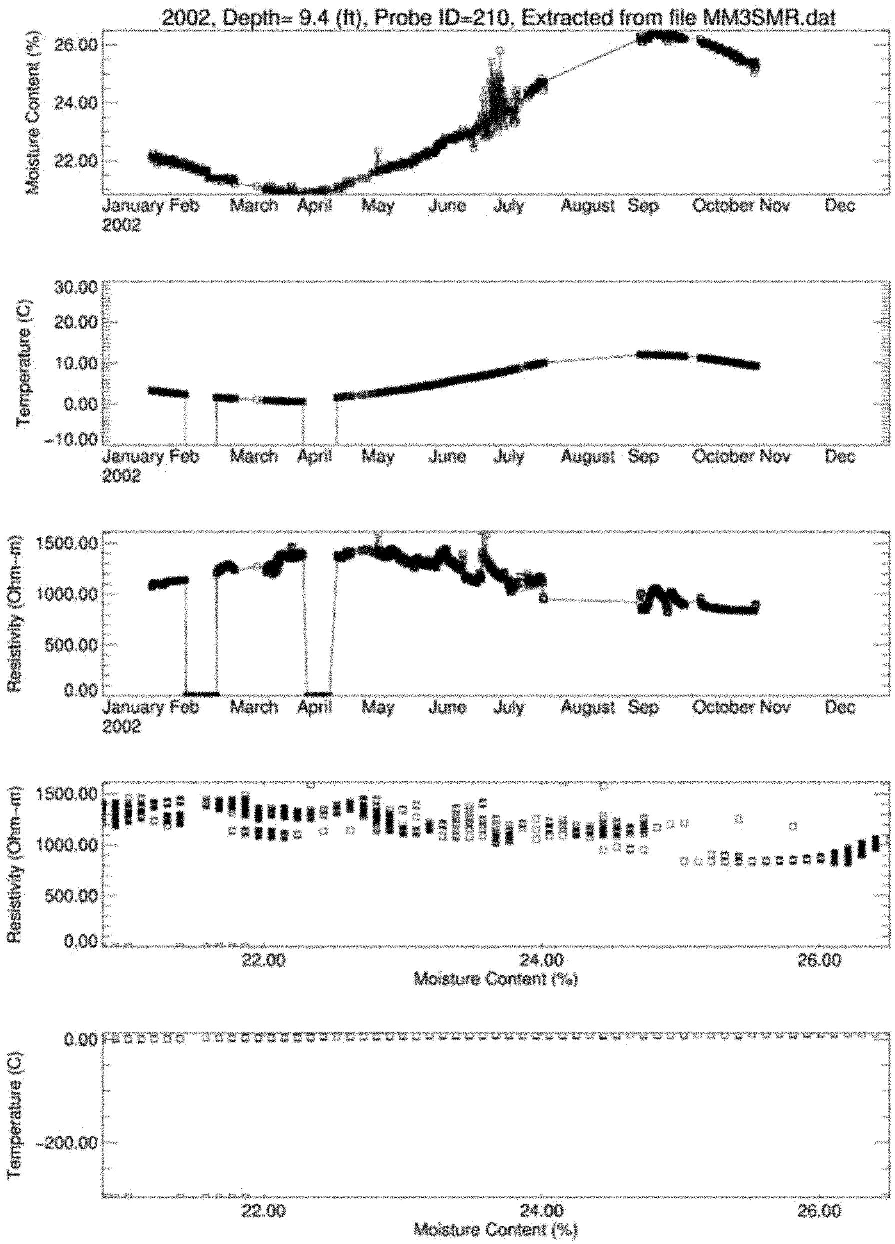
2002, Depth=12.5 (ft), Probe ID=241, Extracted from file MM2SMR.dat



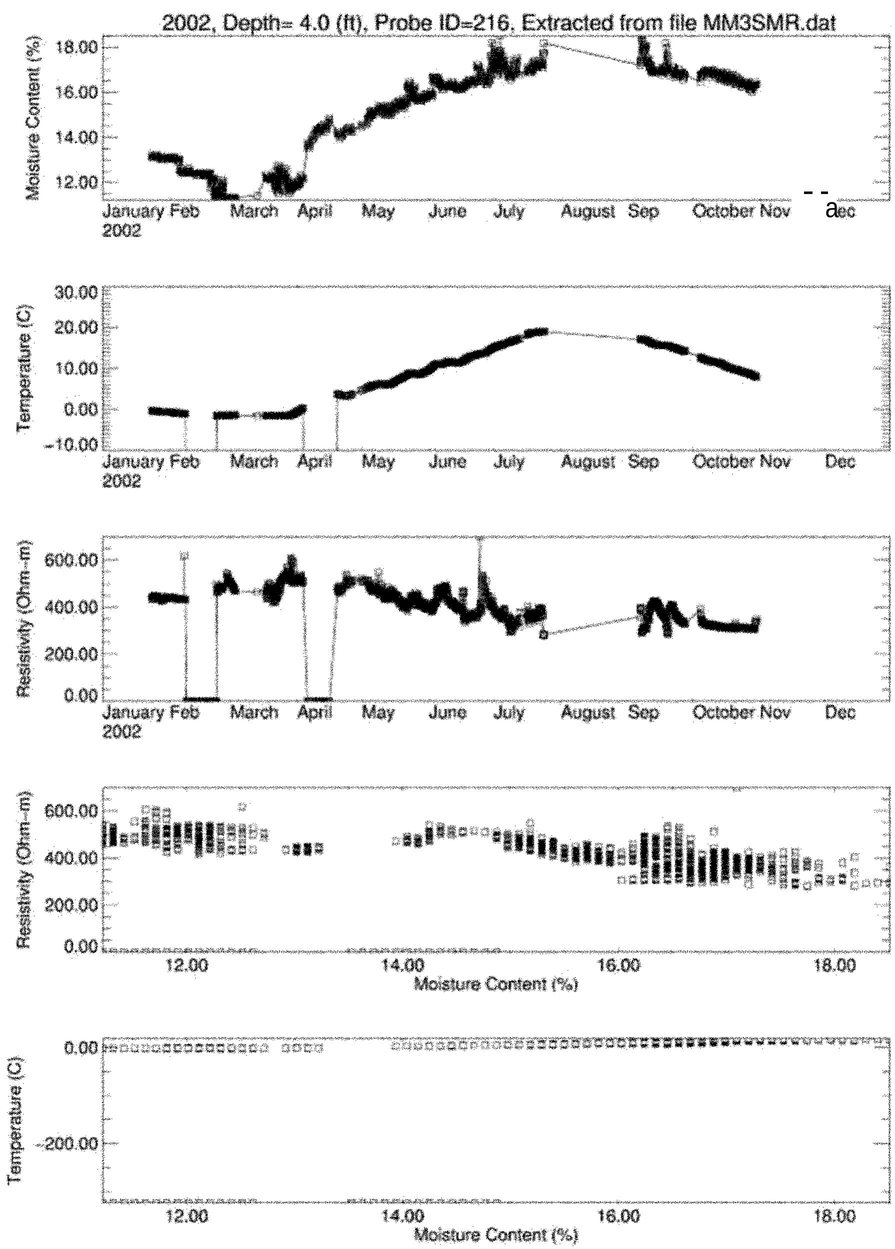
03-GA50310-157



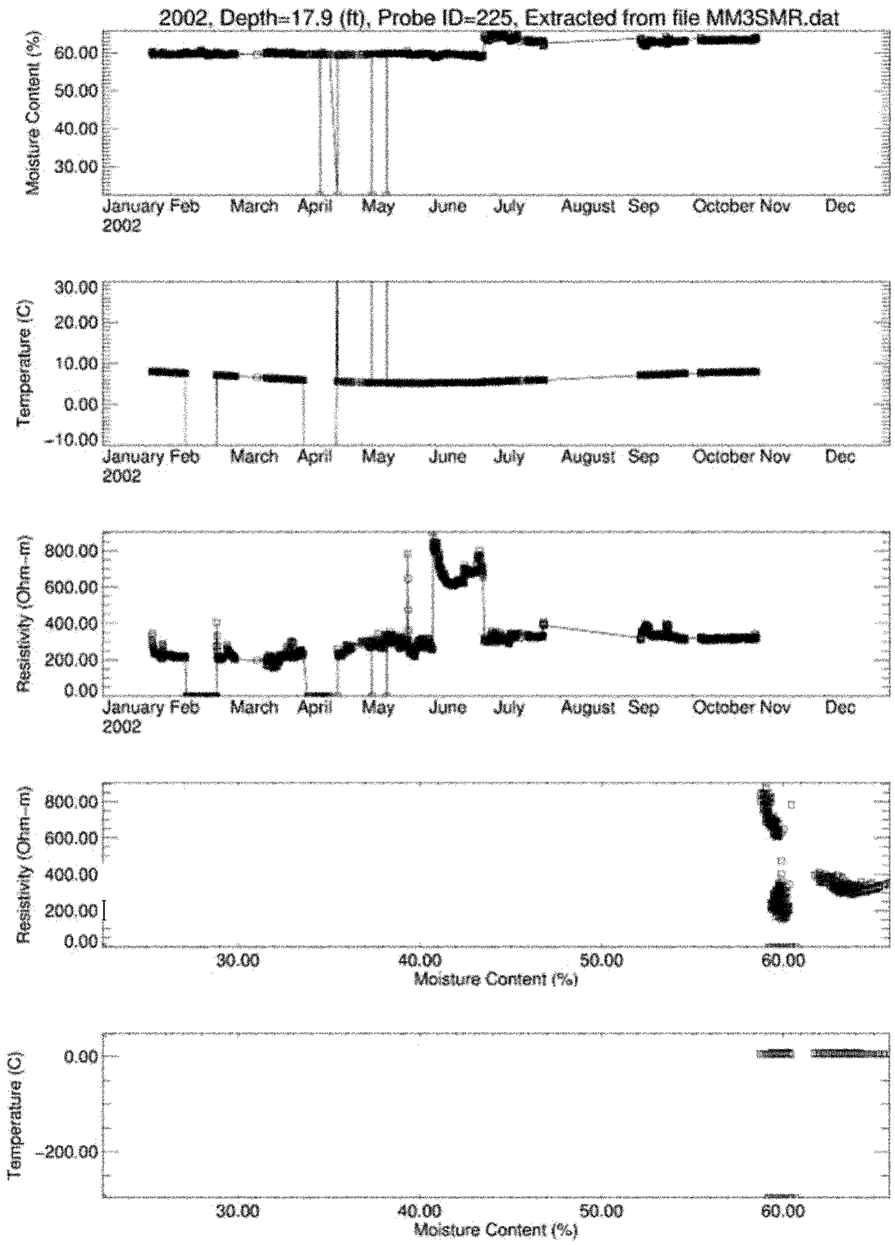
03-GA50310-158



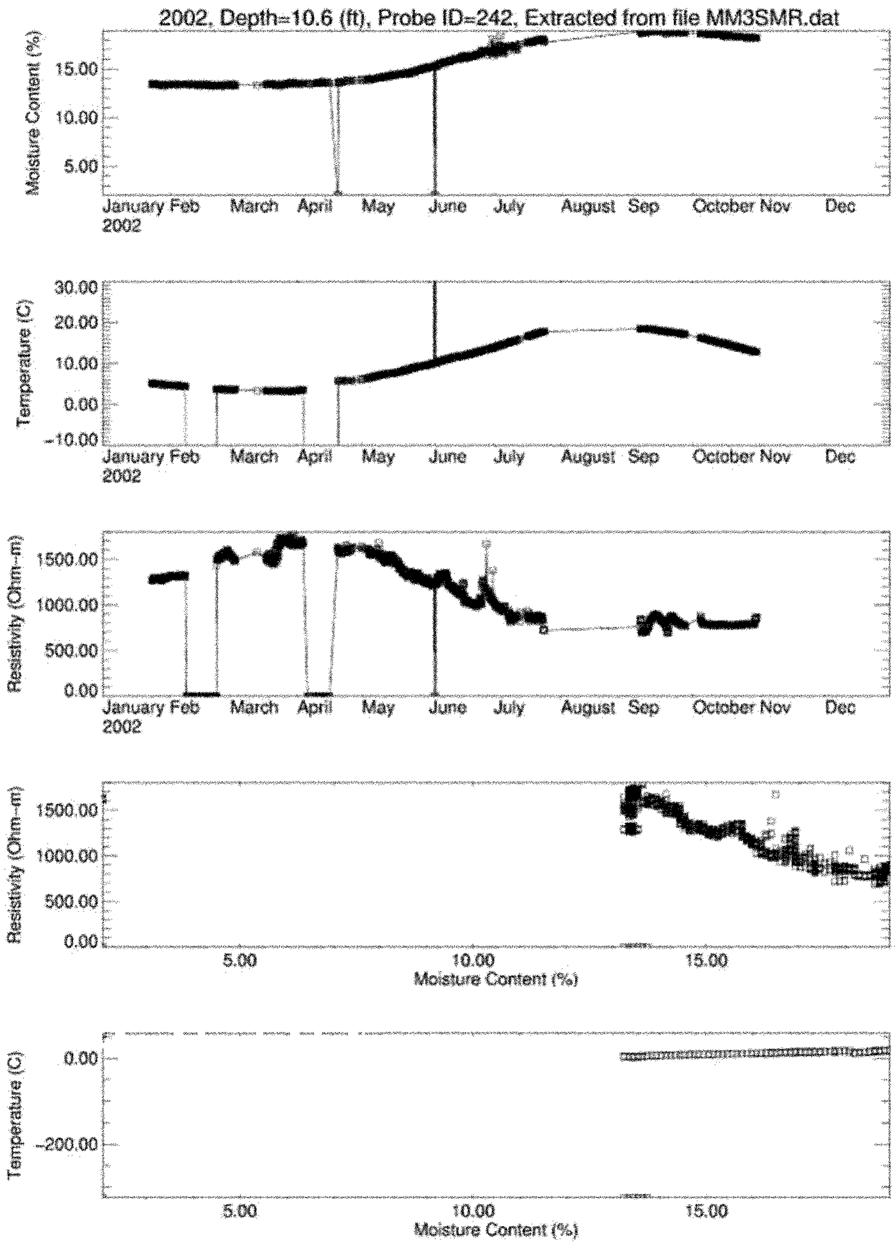
03-GA50310-159



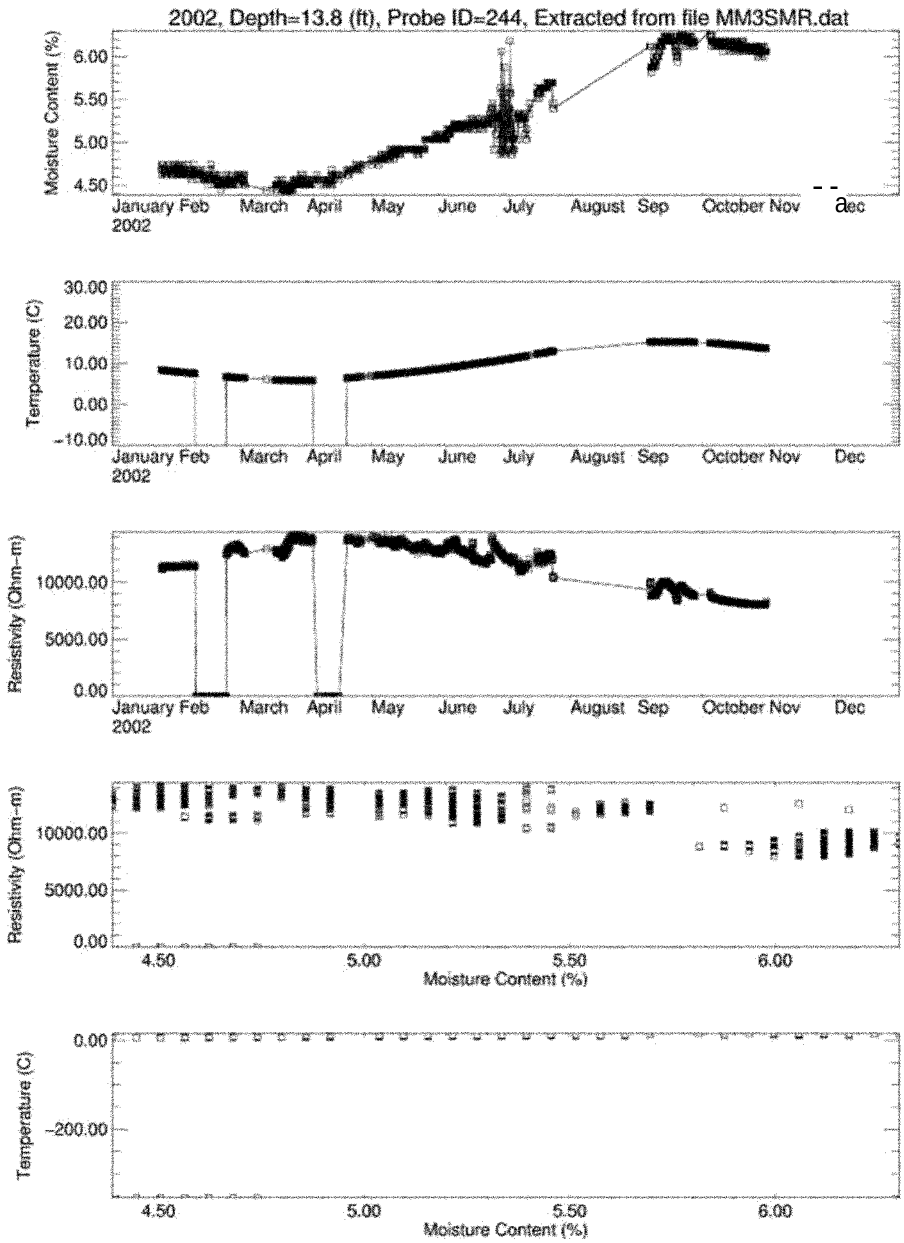
03-GA50310-160



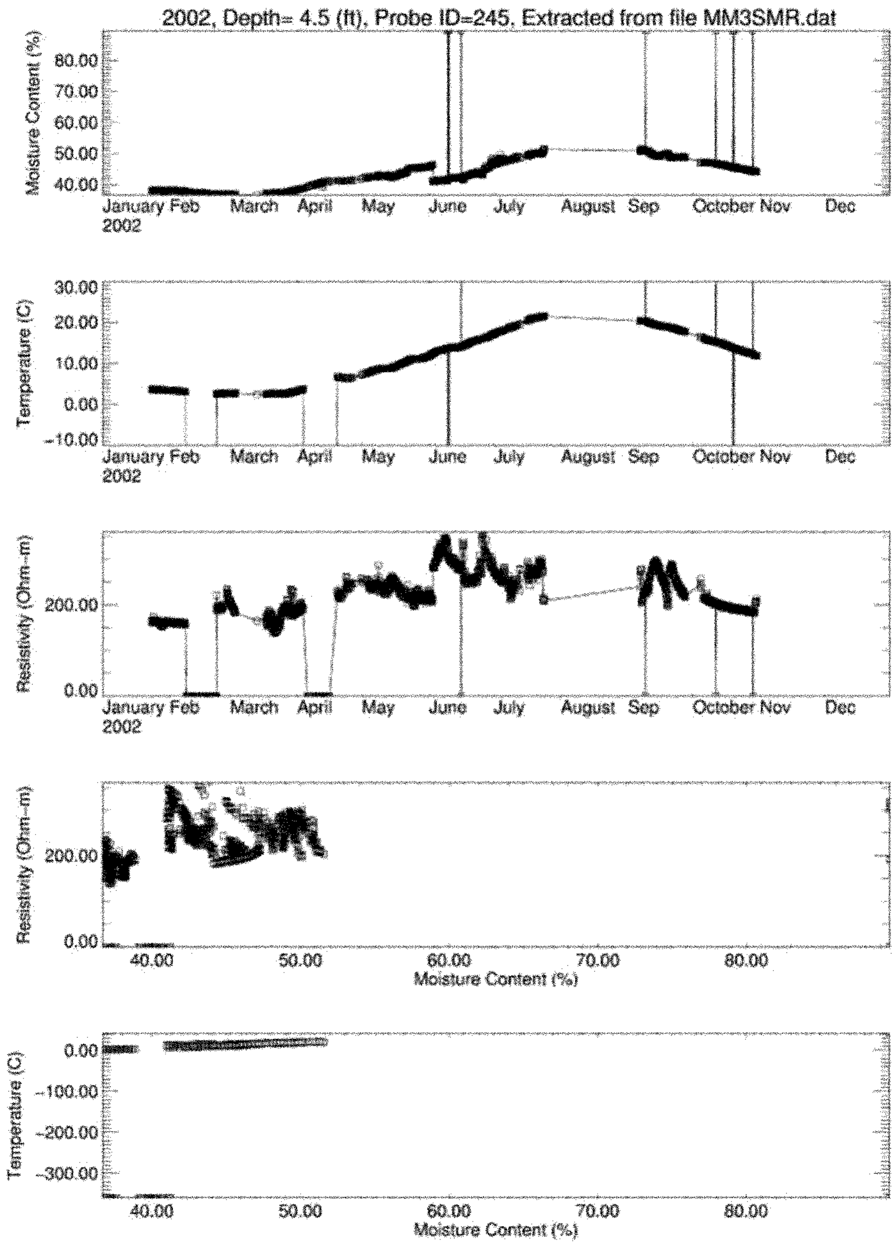
03-GA50310-161



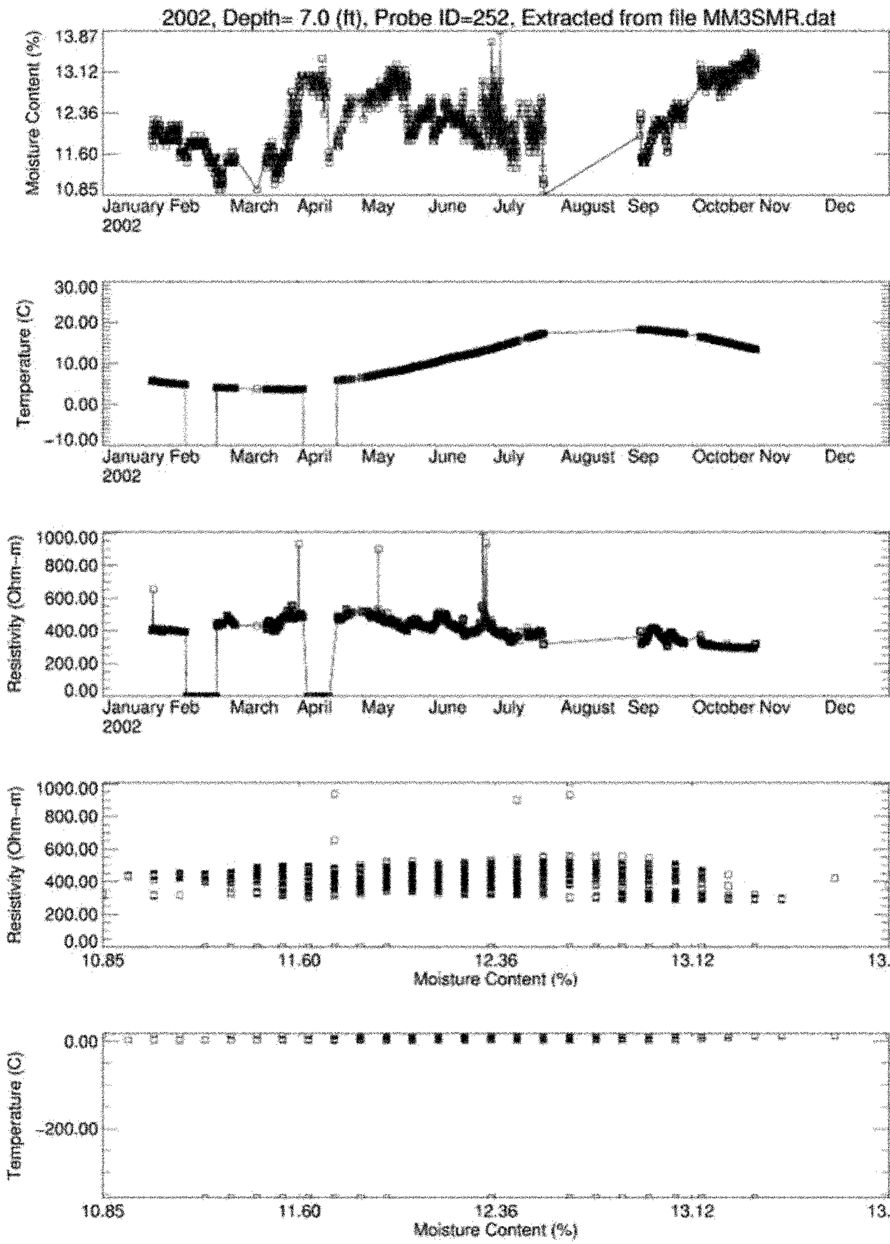
03-GA50310-162



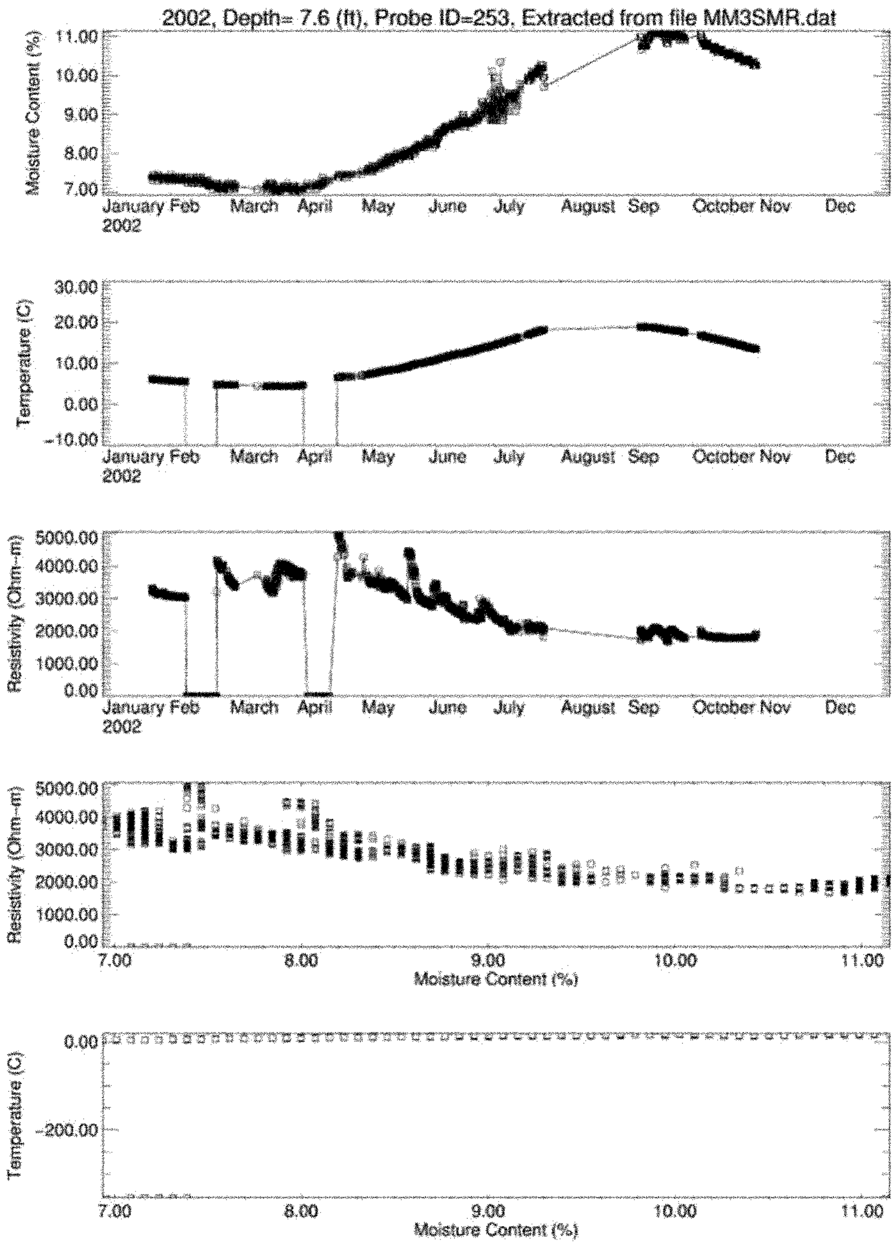
03-GA50310-163



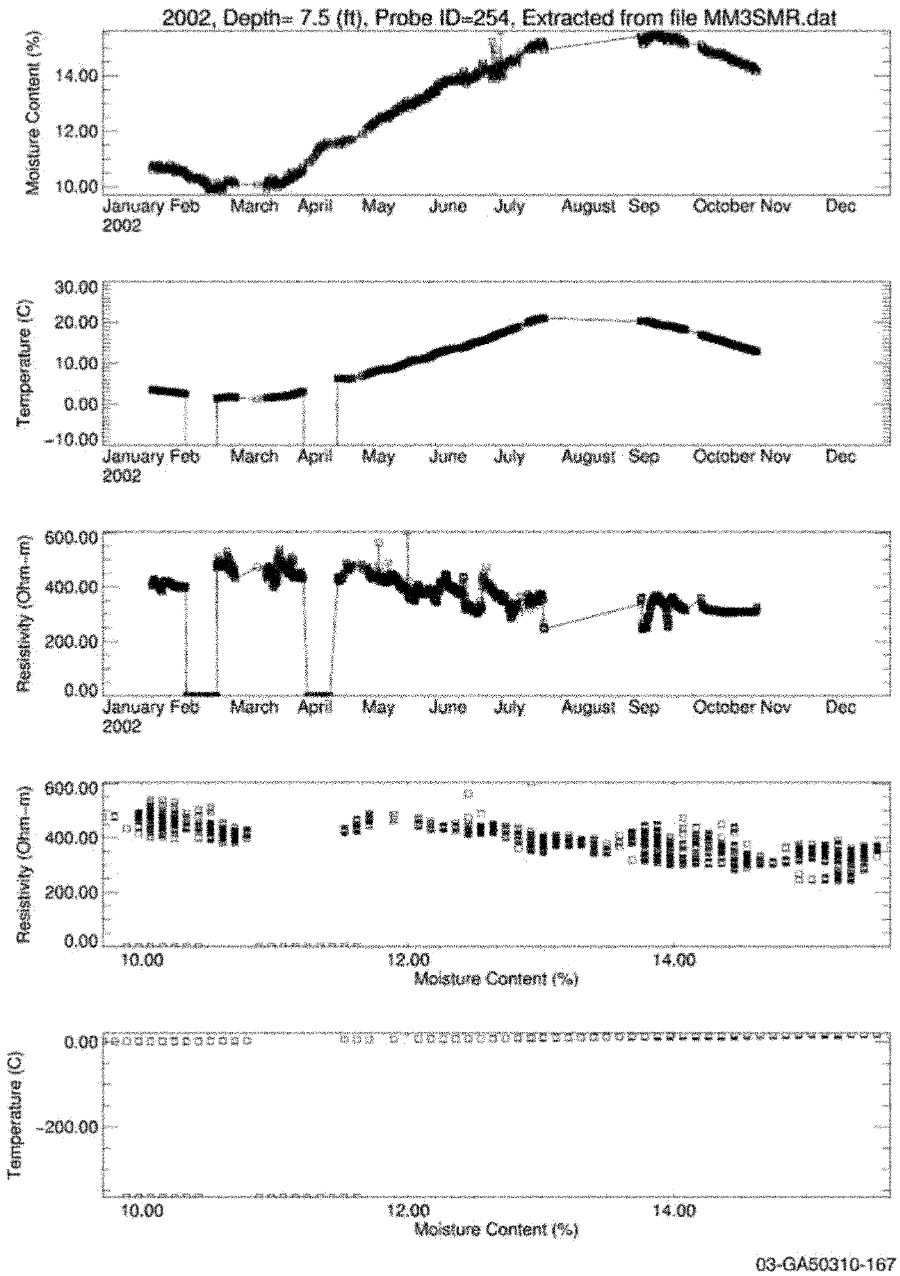
03-GA50310-164



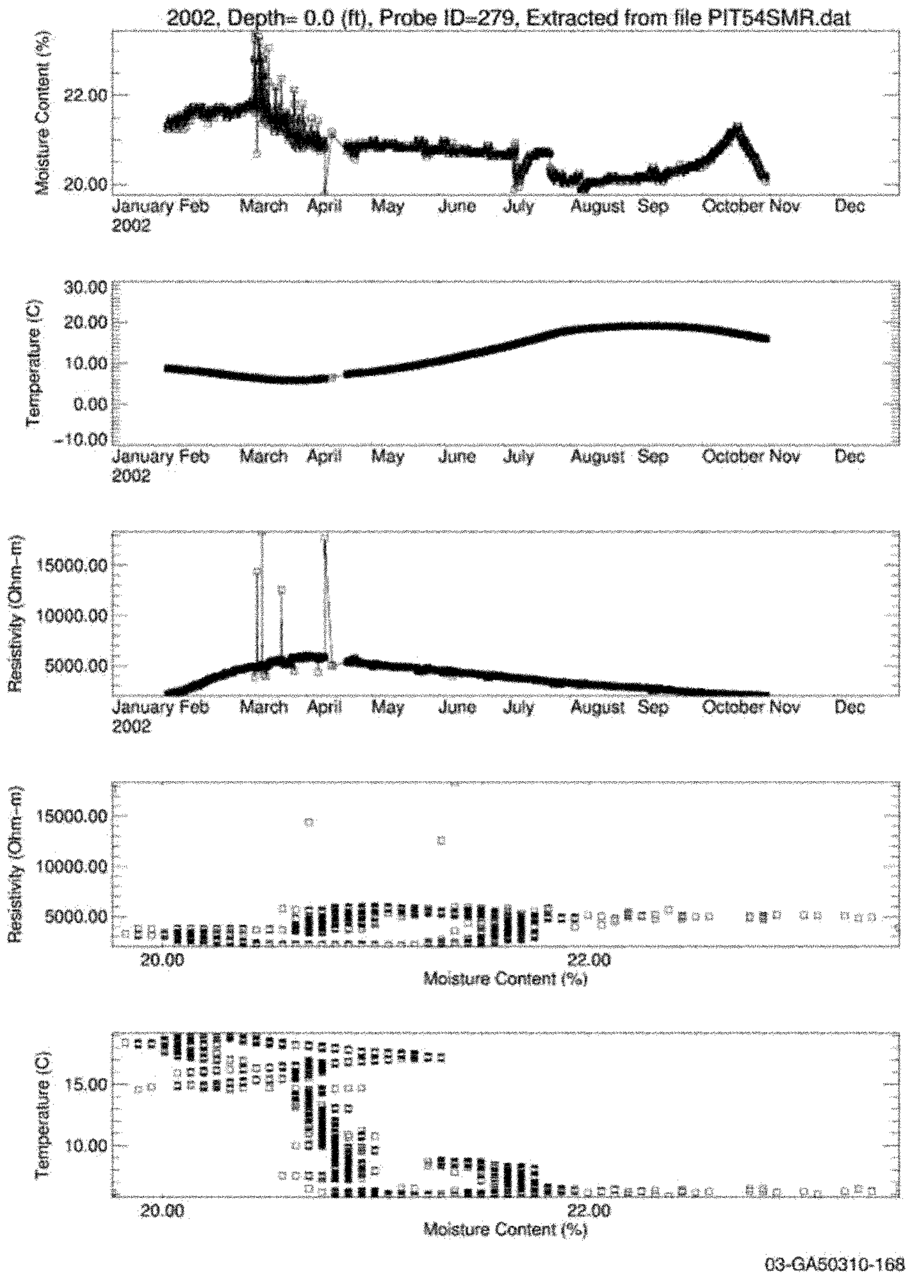
03-GA50310-165

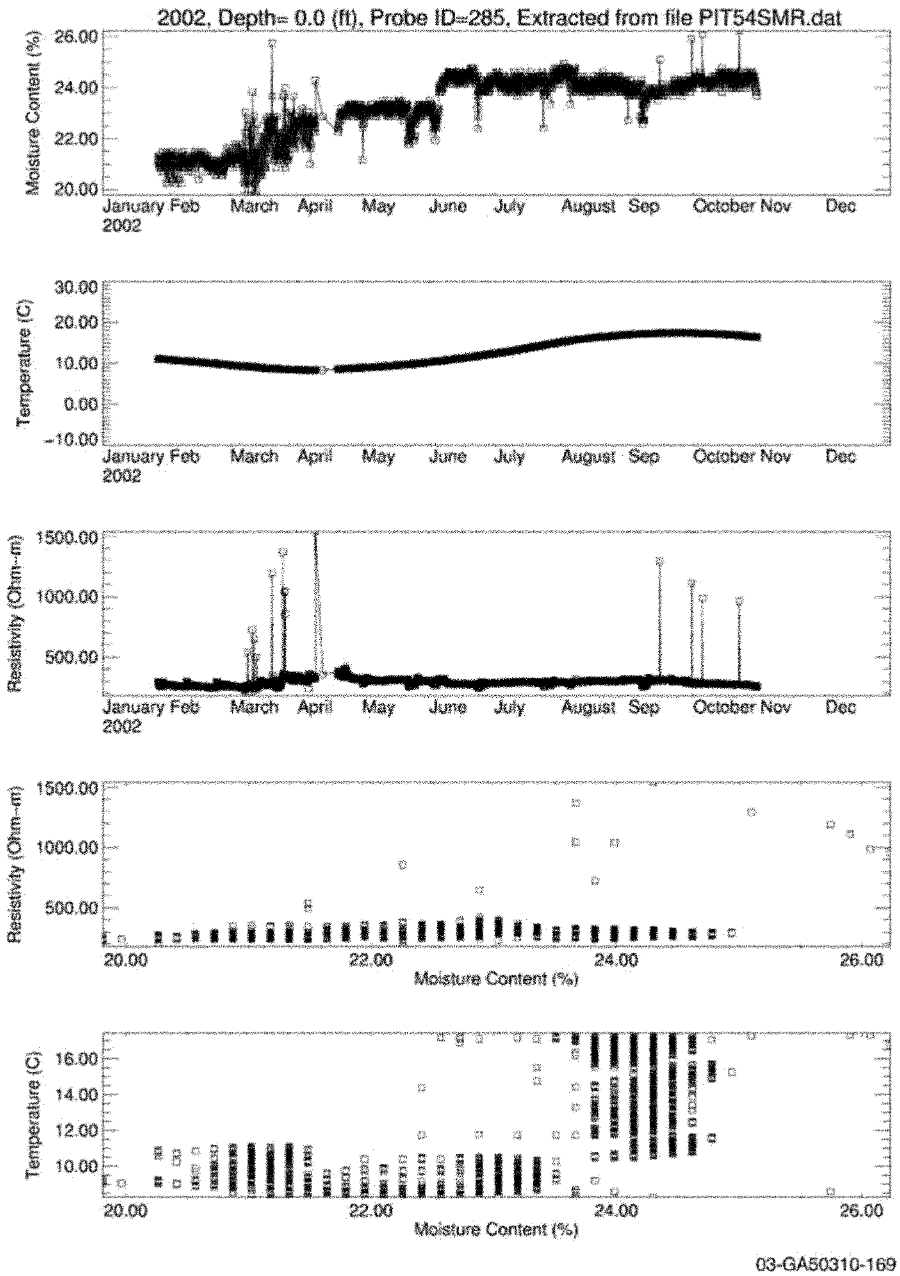


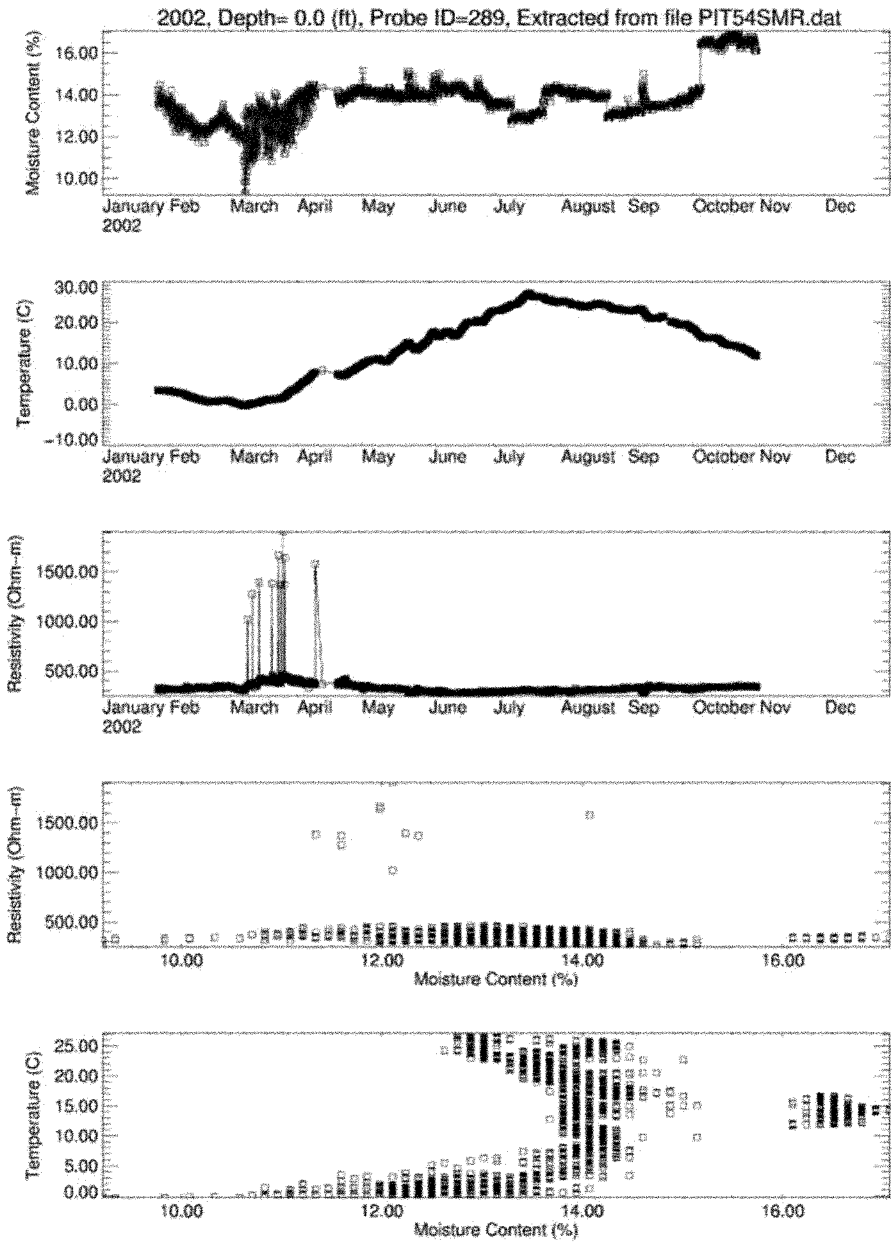
03-GA50310-166



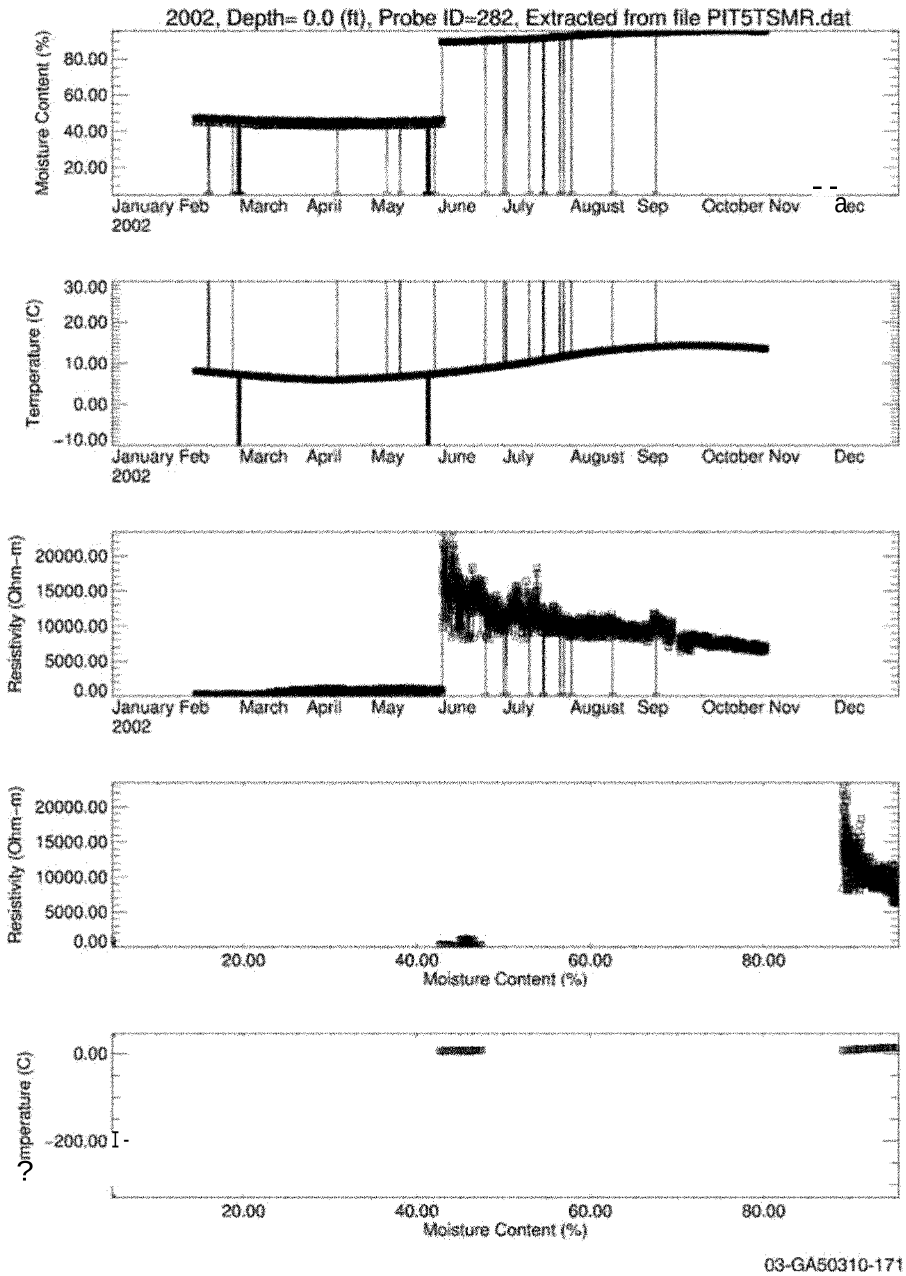
2002, Depth= 7.5 (ft), Probe ID=254, Extracted from file MM3SMR.dat
Moisture Content (%)
14.00
12.00
10.00
January Feb March April May June July August Sep October Nov Dec
2002
Temperature (C)
30.00
20.00
10.00
0.00
-10.00
January Feb March April May June July August Sep October Nov Dec
2002
Resistivity (Ohm-m)
600.00
400.00
200.00
0.00
January Feb March April May June July August Sep October Nov Dec
2002
Resistivity (Ohm-m)
600.00
400.00
200.00
0.00
10.00
12.00
14.00
Moisture Content (%)
Temperature (C)
0.00
-200.00
10.00
12.00
14.00
Moisture Content (%)
03-GA50310-167

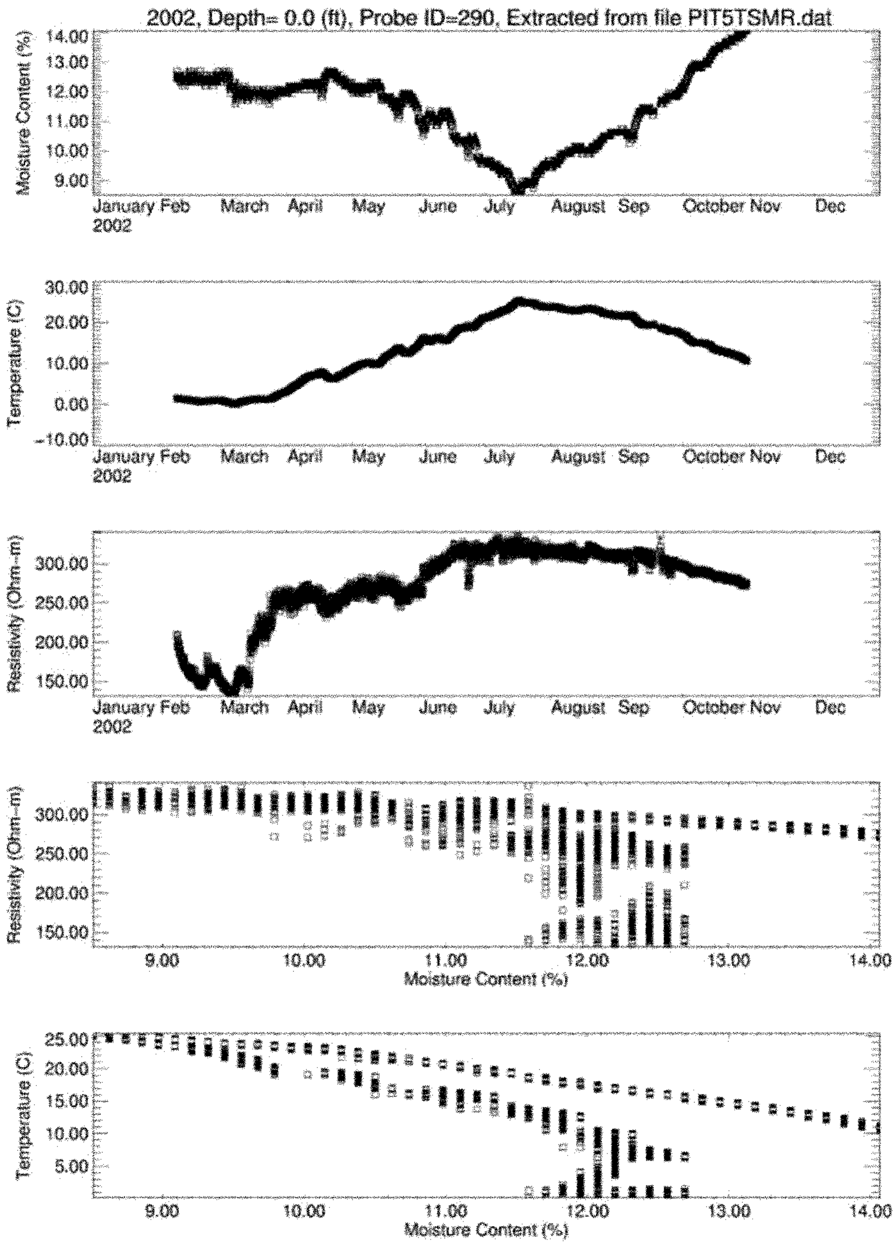

2002, Depth= 0.0 (ft), Probe ID=279, Extracted from file PIT54SMR.dat
Moisture Content (%)
22.00
20.00
January 2002
Feb
March
April
May
June
July
August
Sep
October
Nov
Dec
Temperature (C)
30.00
20.00
10.00
0.00
-10.00
Resistivity (Ohm-m)
15000.00
10000.00
5000.00
Moisture Content (%)
15.00
03-GA50310-168


2002, Depth= 0.0 (ft), Probe ID=285, Extracted from file PIT54SMR.dat
Moisture Content (%)
26.00
24.00
22.00
20.00
January 2002
Feb
March
April
May
June
July
August
Sep
October
Nov
Dec
Temperature (C)
30.00
20.00
10.00
0.00
-10.00
Resistivity (Ohm-m)
1500.00
1000.00
500.00
Moisture Content (%)
20.00
22.00
24.00
26.00
16.00
14.00
12.00
10.00
03-GA50310-169

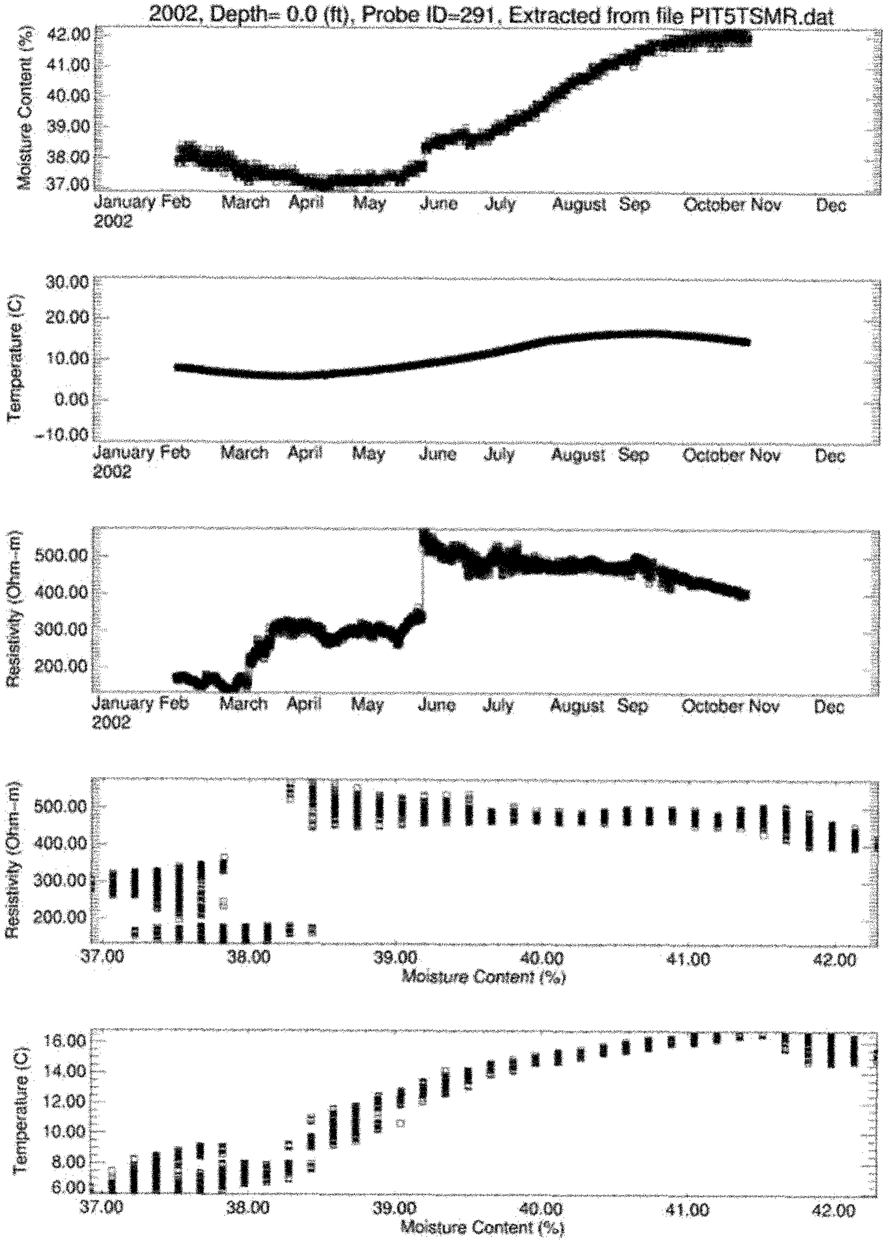


03-GA50310-170

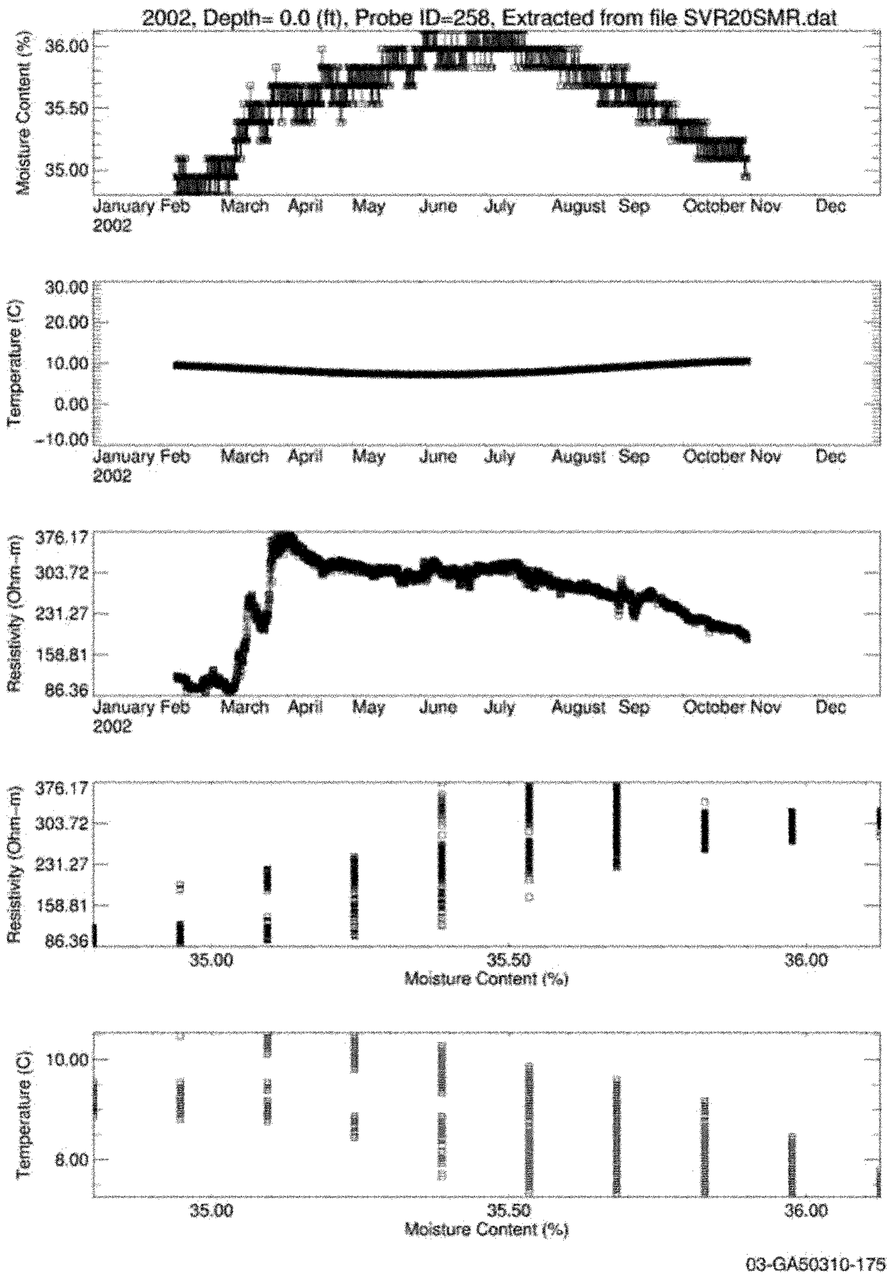

2002, Depth= 0.0 (ft), Probe ID=282, Extracted from file PIT5TSMR.dat
Moisture Content (%)
Temperature (C)
Resistivity (Ohm-m)
January 2002
Feb
March
April
May
June
July
August
Sep
October
Nov
Dec
Moisture Content (%)
03-GA50310-171

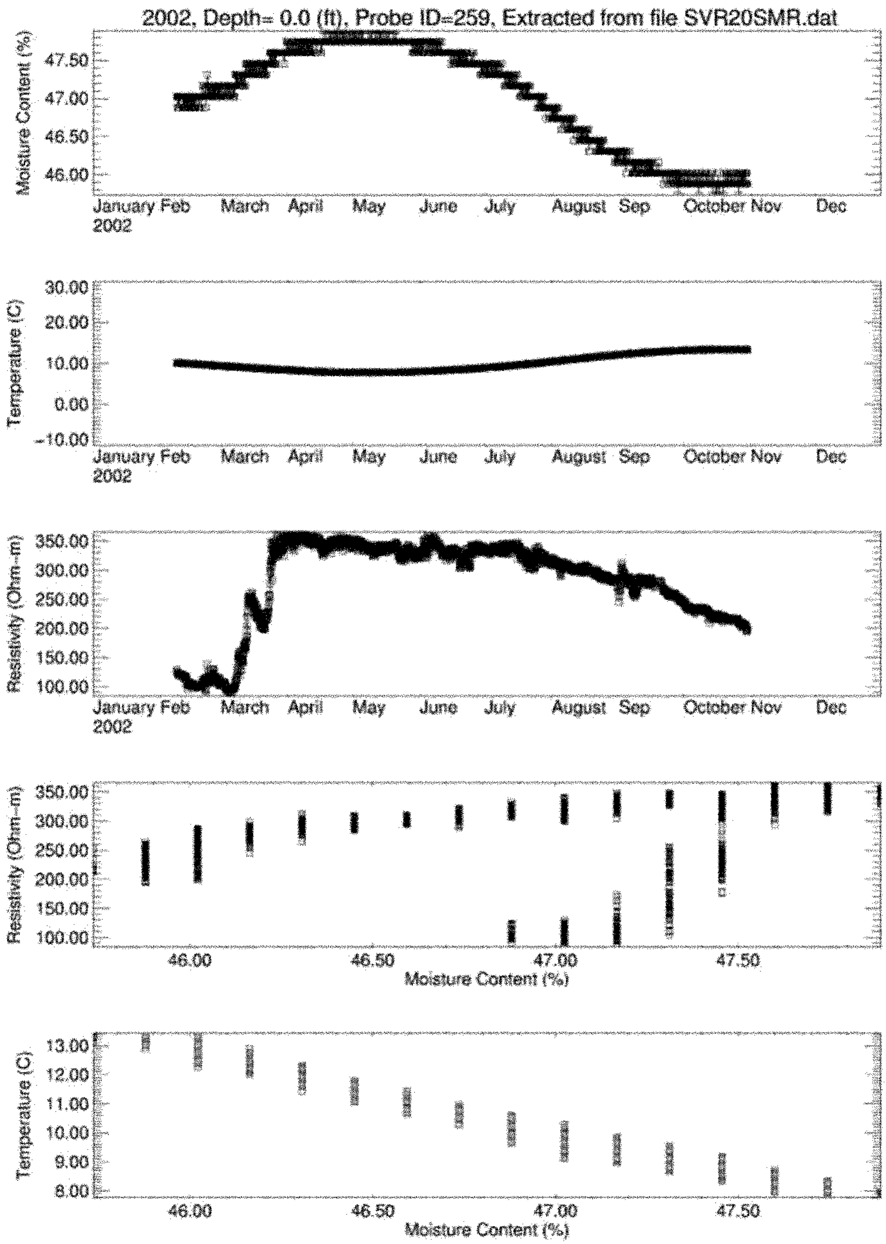


03-GA50310-172



03-GA50310-174


2002, Depth= 0.0 (ft), Probe ID=258, Extracted from file SVR20SMR.dat
Moisture Content (%)
36.00
35.50
35.00
January 2002
Feb
March
April
May
June
July
August
Sep
October
Nov
Dec
Temperature (C)
30.00
20.00
10.00
0.00
-10.00
Resistivity (Ohm-m)
376.17
303.72
231.27
158.81
86.36
Moisture Content (%)
8.00
03-GA50310-175



03-GA50310-176